

Effects of Drought on Climates in Texas

by

Katie Lynn Born, B.S.

Report

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The Report committee for Katie Lynn Born

Certifies that this is the approved version of the following report:

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APPROVED BY SUPERVISING COMMITTEE:

Supervisor: _____

David Maidment

Daene McKinney

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Katie Lynn Born, M.S.

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Supervisor: David Maidment and Daene McKinney

Drought is a growing global concern with severe ramifications for humanity. Texas is one of many places that faces recurring severe droughts, threatening the livelihood of its people. Within the bounds of Texas there are many different climates, and drought can effect these climates differently. The south east edge of the state tend to have a more humid temperate climate, whereas to the north west it becomes hot and arid. Within one state, the climate goes from subtropical to desert. This opens up the state to a lot of variability as to water supply.

This Master's Report investigates the effects that drought has on the varied climates within Texas. Five areas in Texas were chosen to represent the most distinctive climatic shifts. Several hydrologic variables area accessed between regions and drought severity. The hydrologic variables examined are the 2-m above ground temperature, evapotranspiration, latent heat flux, sensible heat flux, net longwave radiation flux, net shortwave radiation flux, total hourly precipitation, and surface runoff. The scope of the

analysis is limited to period of January 2000 to January 2013. Two one month periods were selected to highlight changes under dry conditions compared to normal to wet conditions; July 2007 and July 2011, respectively.

In all of the areas examined, the earth was shown to be parched and dry after periods of less than average precipitation and more willing to take in water than leave it to be surface runoff. An initial investigation into the climates of the five areas showed that the temperatures in the more southeastern regions were more dramatically affected by the occurrence of drought. When drought came along to these southeastern regions, it transformed the climate into something more similar to that typically found in the northwestern regions. The more humid areas to the south east were consistently more dramatically affected by the drought than the arid regions to the north west. The more arid climates started out more similar to that of a drought ridden zone, leaving less room to change. However, all of the areas are significantly impacted by drought through a declining water supply.

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Introduction

Goal

The goal of this report is to analyze drought in five very different climatic regions of Texas through various hydrologic variables. The Data Rods Explorer application was used to obtain data for visual comparison of some of these hydrologic variables. To further the analysis, data values were also obtained from NASA's NLDAS database by Dr. David Arctur. The hydrologic variables that will be examined are the 2-m above ground temperature, evapotranspiration, latent heat flux, sensible heat flux, net longwave radiation flux, net shortwave radiation flux, total hourly precipitation, and surface runoff. Brief explanations of all of the variables available through the database can be found on NASA's Goddard Earth Sciences Data and Information Services website ⁸.

Five areas in Texas were chosen to focus on as they represent diverse environmental regions of the state; coastal in the South, desert to the West, high plains to the North, wooded to the East, and central where they all bleed together. These areas are represented by one of their major cities, Corpus Christi (HUC 12100407), El Paso (HUC 13040100), Amarillo (HUC 11090105), Texarkana (HUC 11140302), and Austin (HUC 12090205), respectively. Figure 1 is a map highlighting these areas via their closest drainage basin. Each area also has a unique fourth level hydraulic unit code (HUC 8)

number as assigned by the United States Geological Survey (USGS) ¹⁰. The HUC 8 values for each area are shown in the key on the map.

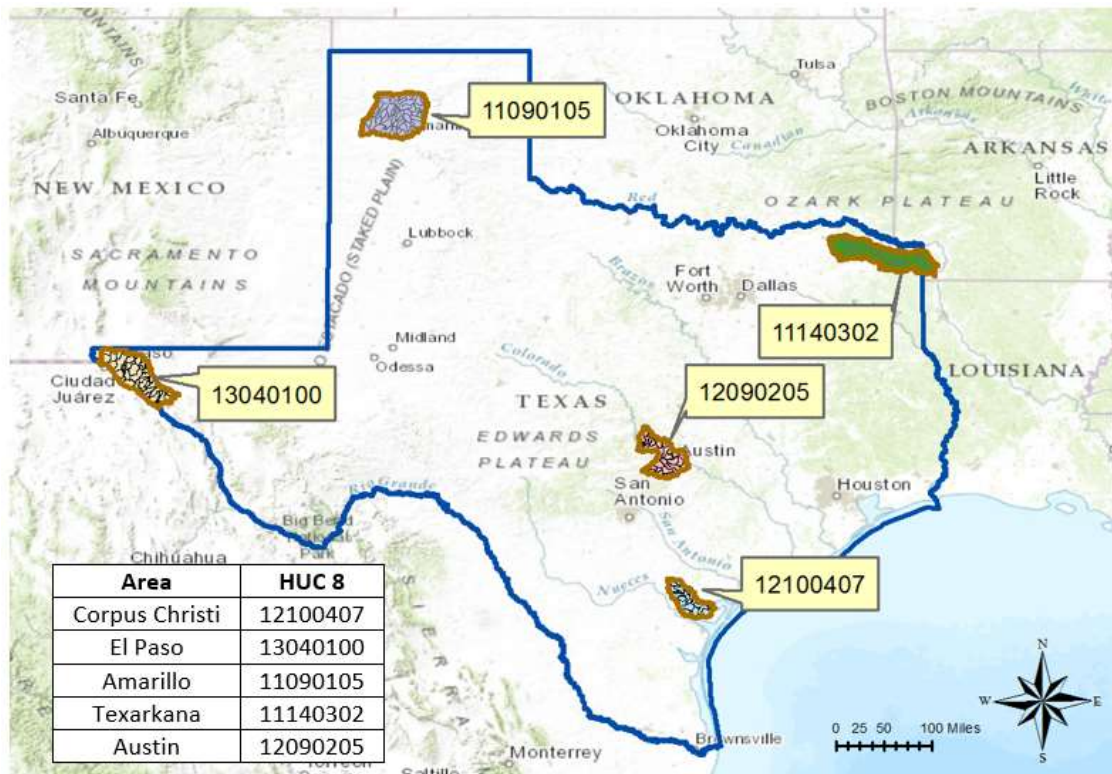


Figure 1: Map of Areas of Interest

Drought

Drought is a constant concern, ever looming with the increasingly unpredictable weather patterns due to global warming. Drought will always be vigilantly monitored, because humanity is completely dependent upon water. Communities and individual households depend on potable water from surface sources as well as groundwater for their everyday consumption and use. Ranch lands rely on water for irrigation to grow crops and raise animals for food supply. Water is the root of all our sources of sustenance. Droughts decrease water levels underground as well as above ground. As

supply starts running short, water prices start going up. If a drought lags on, choices have to be made about who gets any water at all. In 2011, a severe drought in the Austin area led the Lower Colorado River Authority, (LCRA), to cut off the water supply for rice farms for the first time in since its inception in the 1930's⁶. Almost every sizable city in Texas has been in a constant state of residential water restrictions for many years now, limiting car washing and lawn watering to a number of days of the week, depending on drought severity.

In many Texas reservoirs, the released water serves as more than water supply, but also provides electrical generation at dam sites. Power generation is also diminished when a reservoir is at lower levels because the water then has a shorter distance to fall. The retained water also serves a recreational function which stimulates the local economy. As a lake dries up, so do the surrounding businesses because demand for their goods and services decline in step with reduced recreational access. If visitors can't get their boats in the water because none of the boat ramps reach the water, the population on the lake, along with the dollars they contribute, decreases dramatically.

Droughts not only effect surface waters, but the ground itself too; making it ripe for fires. In September 2011, a series of wildfires spread across Texas. The most remarkable of which was in Bastrop County, which scorched 34,000 acres and consumed over 1,000 homes⁴. The more recent fires in Bastrop County in the summer of 2015 were a fraction of what was seen in 2011.

Methodology

To limit the scope of this project, there are time and location constraints for the data accessed. The basis for this report is data collected from January 2000 to January 2013, in locations chosen to represent the diverse climactic zones in Texas. These areas were chosen as cities deep within each ecological zone, and further defined by their nearest drainage basin as a frame of reference. These basin shapefiles were used to eliminate the excess data not pertaining to the areas of interest using ArcGIS tools.

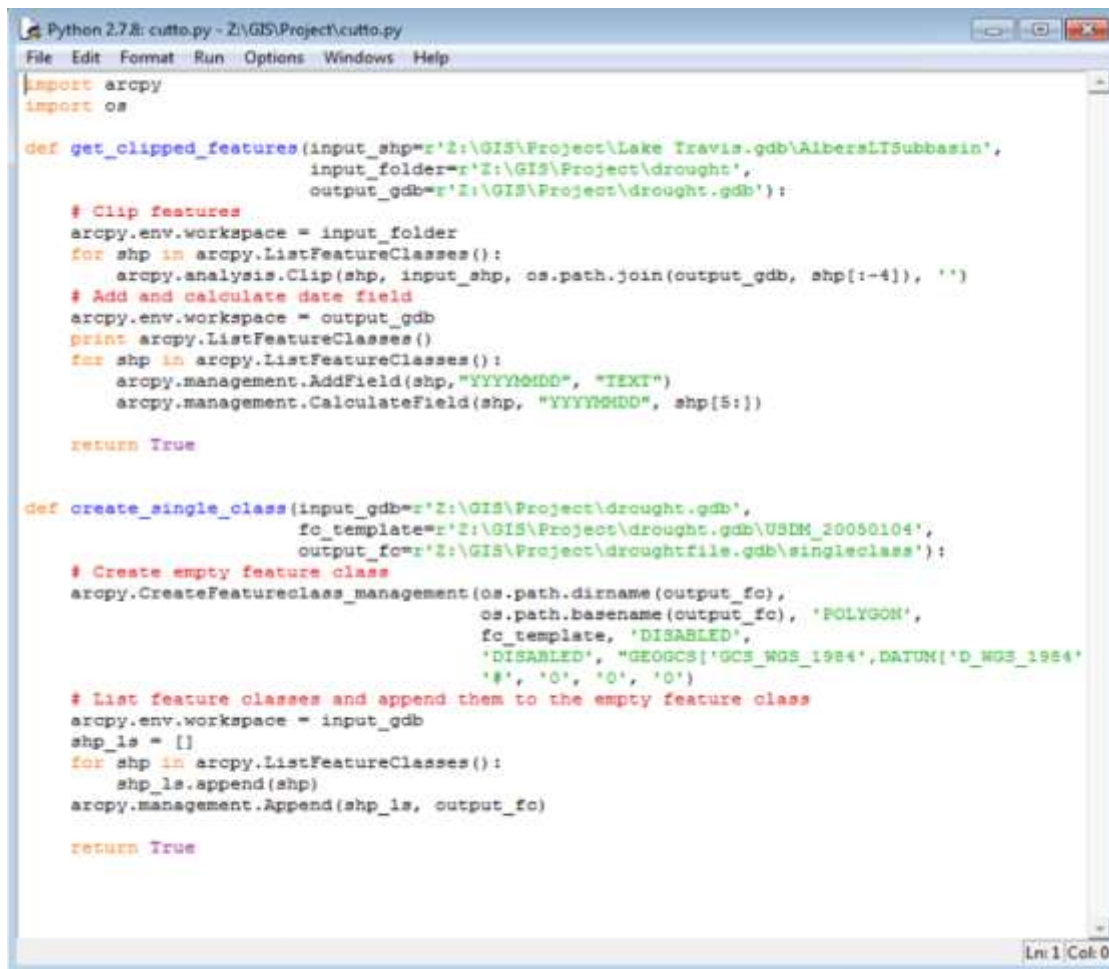
Drought Severity

Drought is categorized into five levels, starting at zero, (D0), and increasing with severity up to D4. These categories are described in Figure 2 by the United States Drought Monitor.

Category	Description	Possible Impacts
D0	Abnormally Dry	Going into drought: <ul style="list-style-type: none">▪ short-term dryness slowing planting, growth of crops or pastures Coming out of drought: <ul style="list-style-type: none">▪ some lingering water deficits▪ pastures or crops not fully recovered
D1	Moderate Drought	<ul style="list-style-type: none">▪ Some damage to crops, pastures▪ Streams, reservoirs, or wells low, some water shortages developing or imminent▪ Voluntary water-use restrictions requested
D2	Severe Drought	<ul style="list-style-type: none">▪ Crop or pasture losses likely▪ Water shortages common▪ Water restrictions imposed
D3	Extreme Drought	<ul style="list-style-type: none">▪ Major crop/pasture losses▪ Widespread water shortages or restrictions
D4	Exceptional Drought	<ul style="list-style-type: none">▪ Exceptional and widespread crop/pasture losses▪ Shortages of water in reservoirs, streams, and wells creating water emergencies

Figure 2: United States Drought Monitor Drought Severity Categories

Data is available for download in raster format nationally as well as tabular format for areas as small as HUC 8 regions from the United States Drought Monitor's website from the year 2000 to the present ⁷. In order to map drought data, the raster must be imported to GIS at the national scale within the 2000 to 2013 time frame and then cut down to fit each basin individually. Gonzalo Espinoza wrote a code which trims the data to the shapefile for each point in time and then compiles all these individual rasters into one time series raster. This script from Gonzalo is shown in Figure 3.

The image shows a screenshot of a Python 2.7 script editor window titled 'Python 2.7.8: cutto.py - Z:\GIS\Project\cutto.py'. The window has a menu bar with 'File', 'Edit', 'Format', 'Run', 'Options', 'Windows', and 'Help'. The script content is as follows:

```
import arcpy
import os

def get_clipped_features(input_shp=r'Z:\GIS\Project\Lake Travis.gdb\AlbersLTSubbasin',
                        input_folder=r'Z:\GIS\Project\drought',
                        output_gdb=r'Z:\GIS\Project\drought.gdb'):

    # Clip features
    arcpy.env.workspace = input_folder
    for shp in arcpy.ListFeatureClasses():
        arcpy.analysis.Clip(shp, input_shp, os.path.join(output_gdb, shp[:-4]), '')
    # Add and calculate date field
    arcpy.env.workspace = output_gdb
    print arcpy.ListFeatureClasses()
    for shp in arcpy.ListFeatureClasses():
        arcpy.management.AddField(shp, "YYYYMMDD", "TEXT")
        arcpy.management.CalculateField(shp, "YYYYMMDD", shp[5:])

    return True

def create_single_class(input_gdb=r'Z:\GIS\Project\drought.gdb',
                        fc_template=r'Z:\GIS\Project\drought.gdb\USDM_20050104',
                        output_fc=r'Z:\GIS\Project\droughtfile.gdb\singleclass'):

    # Create empty feature class
    arcpy.CreateFeatureclass_management(os.path.dirname(output_fc),
                                        os.path.basename(output_fc), 'POLYGON',
                                        fc_template, 'DISABLED',
                                        'DISABLED', "GEOGCS['GCS_WGS_1984',DATUM['D_WGS_1984',
                                        'Spheroid['G', '0', '0', '0']

    # List feature classes and append them to the empty feature class
    arcpy.env.workspace = input_gdb
    shp_ls = []
    for shp in arcpy.ListFeatureClasses():
        shp_ls.append(shp)
    arcpy.management.Append(shp_ls, output_fc)

    return True
```

The status bar at the bottom right of the window shows 'Ln: 1 Col: 0'.

Figure 3: Drought Data Management Code

As an example of this data trimmed down to fit on one of the basins, Figure 4 shows the drought severity information for the Austin area basin on May 17, 2011. With time series data, only one point in time is visible at once.

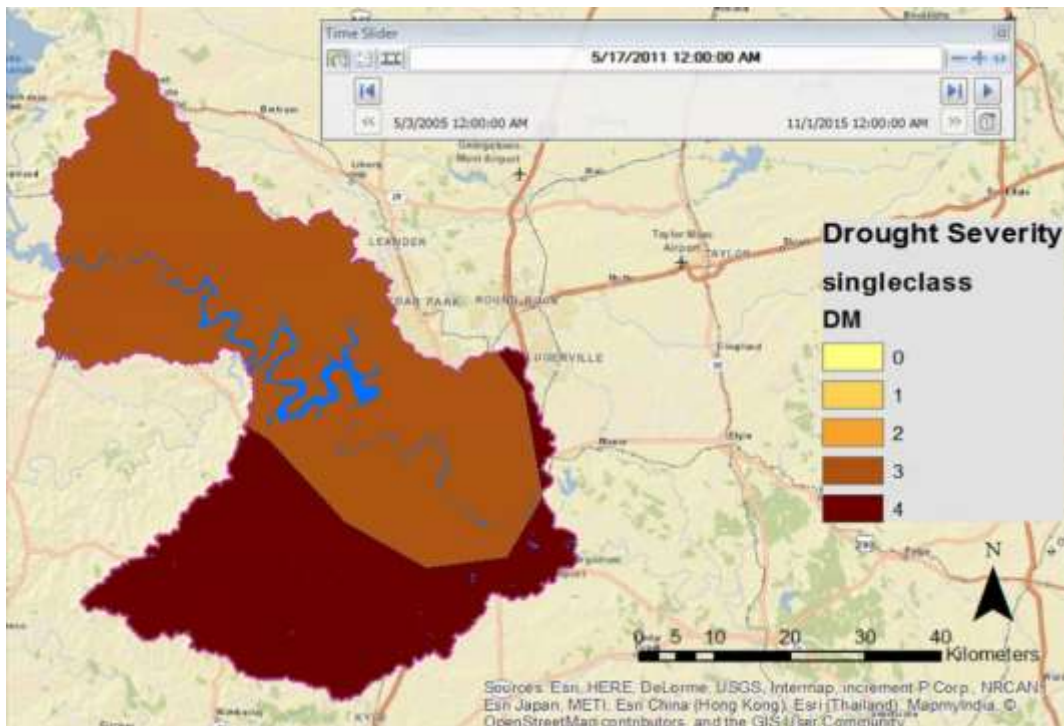


Figure 4: Drought Severity in the Austin Area Basin 17 May 2011

The tabular drought severity data was imported to Excel for each of the five drainage basins with a percent area assigned to each drought category. For each data point, an overall average drought severity grade for the basin was calculated by weighing the percent area at each drought category. “No drought” was given a value of 0 and the drought severity categories D0 – D4 were ranked increasingly from 1 to 5. There are three data points per month, so these were averaged to make an average monthly drought severity grade for each location. As an example, this method resulted in a

drought severity grade of 4.37 for May 2011 in the Austin area; referring to Figure 4 indicates the validity of this method since all of the basin is rated either a 3 or 4 (weighted 4 and 5, respectively), with the majority being a 3. The drought severity over the entire time frame is graphed for each location shown in Figure 5. The monthly drought severity data is shown in tables for each location in Tables 1 through 5.

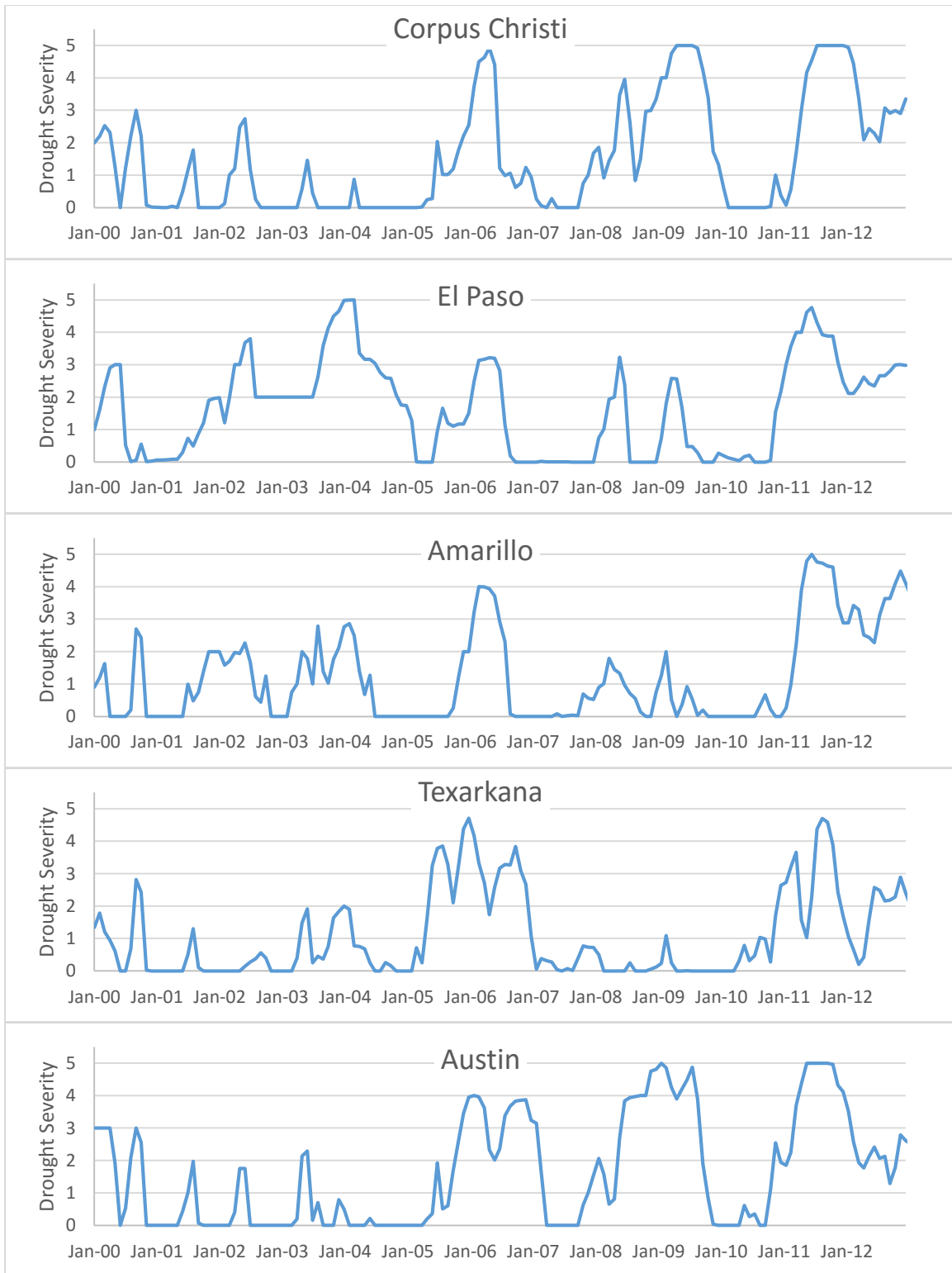


Figure 5: Drought Severity Charts

Table 1: Corpus Christi Average Monthly Weighted Drought Severity

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
2000	2.00	2.20	2.53	2.32	1.26	0.00	1.23	2.21	3.00	2.20	0.08	0.02
2001	0.01	0.00	0.00	0.04	0.00	0.49	1.15	1.78	0.00	0.00	0.00	0.00
2002	0.00	0.13	1.00	1.20	2.48	2.74	1.18	0.25	0.00	0.00	0.00	0.00
2003	0.00	0.00	0.00	0.00	0.58	1.46	0.44	0.00	0.00	0.00	0.00	0.00
2004	0.00	0.00	0.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2005	0.00	0.00	0.00	0.02	0.24	0.28	2.04	1.02	1.02	1.19	1.77	2.21
2006	2.54	3.74	4.50	4.63	4.93	4.41	1.21	0.99	1.06	0.62	0.75	1.24
2007	0.95	0.26	0.06	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.75	1.00
2008	1.68	1.86	0.91	1.45	1.76	3.47	3.95	2.63	0.83	1.50	2.97	2.99
2009	3.34	4.00	4.00	4.75	5.00	5.00	5.00	5.00	4.92	4.24	3.39	1.73
2010	1.33	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	1.00
2011	0.37	0.08	0.56	1.68	3.01	4.16	4.54	5.00	5.00	5.00	5.00	5.00
2012	5.00	4.94	4.44	3.37	2.09	2.44	2.29	2.03	3.07	2.91	2.99	2.90
2013	3.35	3.19	3.77	3.92	3.53	3.31	3.56	3.40	2.60	2.17	1.85	2.24

Table 2: El Paso Average Monthly Weighted Drought Severity

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
2000	1.00	1.61	2.32	2.90	3.00	3.00	0.52	0.01	0.06	0.55	0.01	0.03
2001	0.07	0.07	0.07	0.09	0.08	0.30	0.73	0.49	0.87	1.20	1.90	1.96
2002	1.99	1.21	1.97	3.00	3.00	3.68	3.80	2.00	2.00	2.00	2.00	2.00
2003	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.62	3.59	4.13	4.49	4.65
2004	4.98	5.00	5.00	3.35	3.17	3.17	3.04	2.76	2.59	2.58	2.08	1.76
2005	1.74	1.28	0.00	0.00	0.00	0.00	0.95	1.66	1.20	1.11	1.17	1.17
2006	1.50	2.48	3.13	3.17	3.22	3.20	2.83	1.14	0.19	0.00	0.00	0.00
2007	0.00	0.00	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
2008	0.00	0.75	1.01	1.94	2.00	3.23	2.38	0.00	0.00	0.00	0.00	0.00
2009	0.00	0.75	1.80	2.58	2.57	1.68	0.48	0.48	0.29	0.00	0.00	0.00
2010	0.27	0.20	0.12	0.08	0.04	0.17	0.21	0.00	0.00	0.00	0.05	1.55
2011	2.16	3.00	3.56	4.00	4.00	4.61	4.76	4.30	3.93	3.89	3.88	3.08
2012	2.47	2.11	2.11	2.33	2.62	2.41	2.35	2.66	2.66	2.80	3.00	3.00
2013	2.98	2.89	2.88	3.41	4.52	4.51	4.21	2.92	1.57	0.82	1.16	1.49

Table 3: Amarillo Average Monthly Weighted Drought Severity

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
2000	0.91	1.20	1.63	0.00	0.00	0.00	0.00	0.20	2.70	2.43	0.00	0.00
2001	0.00	0.00	0.00	0.00	0.00	0.00	0.99	0.48	0.75	1.39	2.00	2.00
2002	2.00	1.58	1.71	1.97	1.94	2.27	1.67	0.61	0.44	1.25	0.00	0.00
2003	0.00	0.00	0.75	1.00	2.00	1.78	1.00	2.79	1.38	1.03	1.76	2.12
2004	2.77	2.86	2.51	1.39	0.67	1.27	0.00	0.00	0.00	0.00	0.00	0.00
2005	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	1.20	2.00
2006	2.00	3.21	4.00	3.99	3.94	3.71	2.93	2.31	0.07	0.00	0.00	0.00
2007	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.03	0.04	0.02	0.70	0.57
2008	0.52	0.90	1.01	1.79	1.45	1.33	0.96	0.71	0.56	0.14	0.00	0.00
2009	0.75	1.26	2.00	0.53	0.00	0.36	0.92	0.53	0.03	0.20	0.00	0.00
2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.67	0.23	0.00
2011	0.00	0.26	0.98	2.21	3.90	4.79	5.00	4.76	4.73	4.64	4.61	3.42
2012	2.88	2.88	3.42	3.29	2.51	2.44	2.28	3.12	3.64	3.64	4.09	4.48
2013	4.10	3.69	3.23	3.50	4.89	4.53	4.27	3.78	3.53	3.21	3.28	3.69

Table 4: Texarkana Average Monthly Weighted Drought Severity

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
2000	1.34	1.78	1.20	0.94	0.61	0.00	0.00	0.68	2.82	2.43	0.02	0.00
2001	0.00	0.00	0.00	0.00	0.00	0.00	0.50	1.30	0.11	0.00	0.00	0.00
2002	0.00	0.00	0.00	0.00	0.00	0.14	0.27	0.37	0.56	0.40	0.00	0.00
2003	0.00	0.00	0.00	0.40	1.48	1.91	0.25	0.45	0.36	0.75	1.63	1.83
2004	2.00	1.89	0.77	0.75	0.68	0.25	0.00	0.00	0.26	0.16	0.00	0.00
2005	0.00	0.00	0.72	0.25	1.60	3.25	3.78	3.85	3.27	2.10	3.22	4.37
2006	4.71	4.17	3.33	2.72	1.74	2.58	3.17	3.28	3.27	3.83	3.09	2.67
2007	1.08	0.06	0.38	0.32	0.28	0.04	0.00	0.07	0.02	0.38	0.77	0.73
2008	0.72	0.50	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.05
2009	0.12	0.24	1.09	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2010	0.00	0.00	0.00	0.00	0.31	0.79	0.31	0.47	1.03	0.98	0.28	1.70
2011	2.64	2.73	3.20	3.65	1.57	1.03	2.28	4.37	4.70	4.58	3.88	2.43
2012	1.68	1.05	0.66	0.20	0.42	1.58	2.57	2.49	2.16	2.18	2.28	2.89
2013	2.39	1.97	2.43	1.88	1.77	0.74	1.93	2.82	3.19	1.43	0.55	0.30

Table 5: Austin Average Monthly Weighted Drought Severity

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
2000	3.00	3.00	3.00	3.00	1.92	0.00	0.53	2.09	3.00	2.56	0.00	0.00
2001	0.00	0.00	0.00	0.00	0.00	0.44	1.00	1.98	0.06	0.00	0.00	0.00
2002	0.00	0.00	0.00	0.40	1.75	1.75	0.00	0.00	0.00	0.00	0.00	0.00
2003	0.00	0.00	0.00	0.20	2.14	2.29	0.15	0.70	0.00	0.00	0.00	0.79
2004	0.50	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.00
2005	0.00	0.00	0.00	0.00	0.20	0.36	1.93	0.51	0.60	1.69	2.60	3.45
2006	3.95	4.00	3.96	3.62	2.33	2.02	2.35	3.38	3.68	3.83	3.85	3.87
2007	3.23	3.15	1.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.63	1.00
2008	1.54	2.07	1.58	0.65	0.81	2.70	3.84	3.94	3.97	4.00	4.00	4.75
2009	4.81	4.99	4.86	4.26	3.90	4.21	4.48	4.87	3.90	1.90	0.83	0.04
2010	0.00	0.00	0.00	0.00	0.00	0.62	0.27	0.35	0.00	0.00	1.09	2.54
2011	1.94	1.85	2.25	3.69	4.37	4.99	5.00	5.00	5.00	5.00	4.97	4.32
2012	4.12	3.51	2.58	1.93	1.77	2.12	2.41	2.06	2.13	1.29	1.77	2.79
2013	2.61	2.50	3.06	3.06	2.77	2.37	2.93	2.93	2.67	1.62	1.20	1.17

Hydrologic Variables

Data for the remaining hydrologic variables of interest can be imported to fit around a basin shapefile using a tool built by Gonzalo Espinoza specifically for downloading raster datasets from NASA's Land Data Assimilation systems (LDAS). This doesn't fit the data exactly to the shape, instead pulling the grid cells surrounding the shape.

To use the tool, “LDAS NOAH downloader”, the toolbox file must be saved in a folder which can be navigated to within the GIS catalog. Once the folder connection has been established, the tool can be opened from the catalog. This is shown in Figure 6, the specific tool highlighted by the red box.

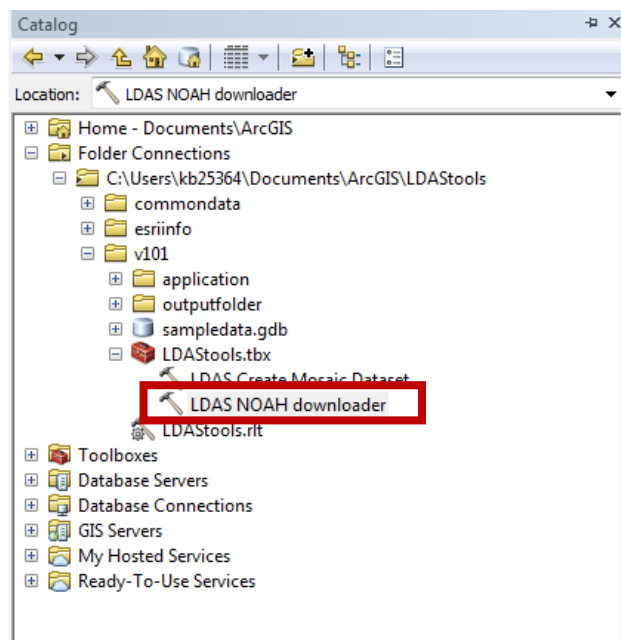


Figure 6: LDAS Toolbox

Once initiated the tool opens a dialog box with six user specified inputs. This dialog box is shown in Figure 7, along with the dropdown options for the data source and variable. The user must have a preexisting shapefile for the “Input study area”, this limits the data acquisition to the area of interest. The shapefile can be dragged from the layers or navigated to as a file. The data source allows the user to choose the grid size and frequency of data points from either the North American Land Data Assimilation System

(NLDAS) or the Global Land Data Assimilation System (GLDAS). The choices of variables depend on the data source selected, the variables shown in Figure 7 are those for the NLDAS – 2 hourly 1/8 degree data source. Then the output workspace should be a folder for the dataset to be saved to. The time frame of the data obtained can be specified with a calendar pop-out.

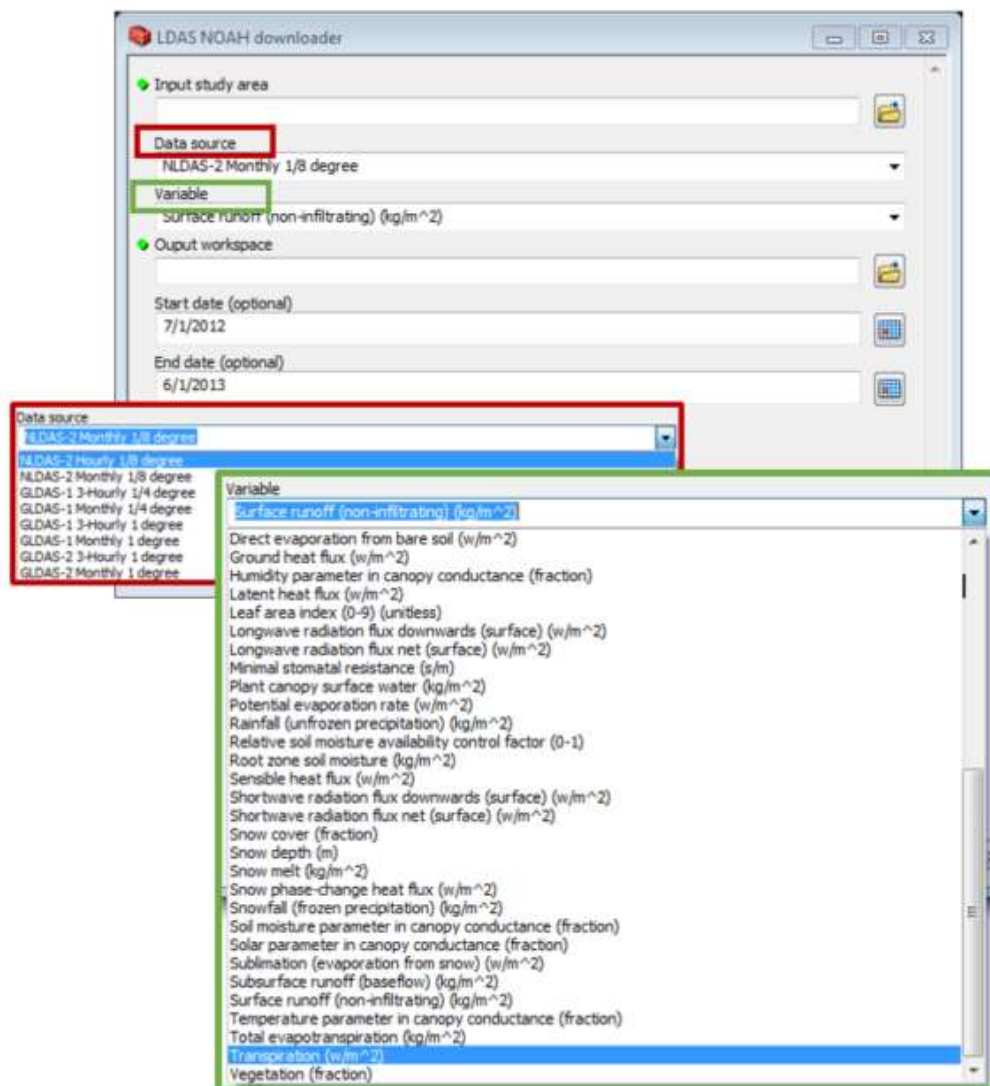


Figure 7: LDAS NOAA Downloader Dialog Box

The tool needs access to the internet in order to download the data specified from the online databases. Once finished, the data for the whole timeframe in the specified area will be saved to the folder specified. An example of what the tool provides is shown in Figure 8 for a single time point within the time frame (February 2011) for the Austin area basin.

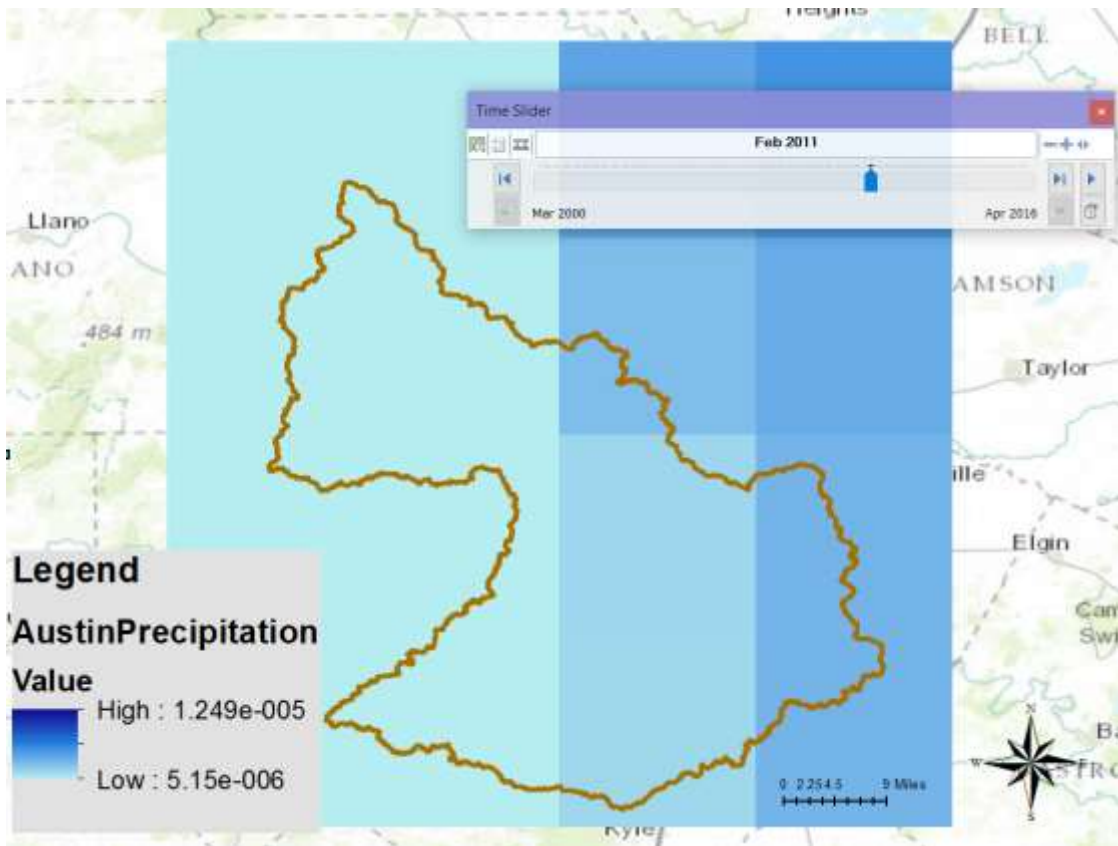


Figure 8: Precipitation in the Austin Area Basin February 2011

The Data Rods Explorer app, built by Gonzalo Espinoza, allows the user to choose a variable or two of interest from a list, a time frame, and click on a location with the

interactive map to plot the time series data specified. The interface is pictured in Figure 9 before any location has been zoomed into.

The Data Rods Explorer is a web app available through Hydroshare, an online metadata sharing site. This app is an easy way to get a visual representation of hydrologic data for an approximate location over a specified time frame, with many hydrologic variables to choose from that get pulled from three different data sets. Plots can be of one variable across a timeframe or year-on-year changes as well as a comparison of two variables across a timeframe.



Figure 9: Data Rods Explorer

While the app is a great way to quickly obtain hydrologic data, there are a few shortcomings. The location is specified by point and click with the mouse; this means that a single grid cell point is chosen in each basin to collect representative data for each

hydrologic variable instead of data for the entire basin. With no way to input latitude and longitude as a parameter, an error is introduced when trying to choose the same location for each variable of interest. The locations chosen for this report are as close to the same for each area as possible. The specific spot chosen for each basin are shown in Figure 10, labeled by the approximate longitude and latitude. Additionally, there is currently no way to download the data points directly from the Data Rods Explorer app, only the graphs that it produces.



Figure 10: Longitude and Latitude of Hydrologic Data Locations

Dr. Arctur retrieved URL's for the hard data for this report from NASA's NLDAS database for the points of latitude and longitude shown in Figure 10. A small portion of the spreadsheet Dr. Arctur compiled is shown in Figure 11. The spreadsheet containing the URLs for every data set can be found in the Appendix.

For Katie Born		4/20/2016
From D.Arctur		
NLDAS variables info: http://disc.sci.gsfc.nasa.gov/hydrology/data-rodas-time-series-data		
Variable	Data Source	
1 2-m above ground temperature	forcing	
2 Surface DW shortwave radiation flux	forcing	
3 Surface DW longwave radiation flux	forcing	
4 evapotranspiration	noah	
5 latent heat flux	noah	
6 sensible heat flux	noah	
7 precip hourly total	forcing	
8 surface runoff	noah	
Corpus Christi		
Wet July 2007		Dry July 2011
1 http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_FORA0125_H.002:TMP2m&startDate=2007-07-01T00&endDate=2007-08-01T00&location=GEOM:POINT%28-97.5785,%2028.1507%29&type=asc2	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_FORA0125_H.002:TMP2m&startDate=2011-07-01T00&endDate=2011-08-01T00&location=GEOM:POINT%28-97.5785,%2028.1507%29&type=asc2	
2 http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_FORA0125_H.002:DSWRFsfc&startDate=2007-07-01T00&endDate=2007-08-01T00&location=GEOM:POINT%28-97.5785,%2028.1507%29&type=asc2	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_FORA0125_H.002:DSWRFsfc&startDate=2011-07-01T00&endDate=2011-08-01T00&location=GEOM:POINT%28-97.5785,%2028.1507%29&type=asc2	
3 http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_FORA0125_H.002:DLWRFsfc&startDate=2007-07-01T00&endDate=2007-08-01T00&location=GEOM:POINT%28-97.5785,%2028.1507%29&type=asc2	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_FORA0125_H.002:DLWRFsfc&startDate=2011-07-01T00&endDate=2011-08-01T00&location=GEOM:POINT%28-97.5785,%2028.1507%29&type=asc2	
4 http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_NOAH0125_H.002:EVPSfc&startDate=2007-07-01T00&endDate=2007-08-01T00&location=GEOM:POINT%28-97.5785,%2028.1507%29&type=asc2	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_NOAH0125_H.002:EVPSfc&startDate=2011-07-01T00&endDate=2011-08-01T00&location=GEOM:POINT%28-97.5785,%2028.1507%29&type=asc2	

Figure 11: LDAS Data Sheet

Each URL specifies the longitude and latitude of the location, the data source, the variable, and the timeframe of interest. This can be seen in the sample URL for the Corpus Christi Temperature data shown in Figure 12. The data specifications are highlighted with red. These parts can be changed to obtain other data from the LDAS database. An in depth explanation of the URL can be found at NASA's Goddard Earth Sciences Data and Information Services Center ². The top of the page that this URL links

to is shown in Figure 13. The data continues further down the page for the entire time frame specified. Each of these pages can be saved as a text documents and opened as an excel document.

The diagram shows a URL with the following components labeled:

- Data Source:** `http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_FORA0125_H.002`
- Variable:** `TMP2m`
- Start Date:** `&startDate=2007-07-01T00`
- Start Time:** `&endDate=2007-08-01T00`
- End Date:** `&endDate=2007-08-01T00`
- End Time:** `&endDate=2007-08-01T00`
- Longitude:** `&location=GEOM:POINT%28-97.5785,%2028.1507%29&type=asc2`
- Latitude:** `&location=GEOM:POINT%28-97.5785,%2028.1507%29&type=asc2`

Figure 12: Example LDAS Data URL

Metadata of the Time Series file:

```
prod_name=NLDAS_FORA0125_H.002
param_short_name=TMP2m
param_name=2-m above ground temperature
unit=k
undef= 9.9990e+20
begin_time=1979/01/01/13
end_time=2016/04/24/12
time_interval[hour]=1
tot_record=327072
grid_y=25 (lat= 28.1875)
grid_x=219 (lon= -97.5625)
elevation[m]=25.320181
dlat=0.125000
dlon=0.125000
ydim(original data set)=224
xdim(original data set)=464
start_lat(original data set)= 25.0625
start_lon(original data set)=-124.9375
Last_update=Thu Apr 28 15:35:26 2016
```

Metadata for Requested Time Series:

```
prod_name=NLDAS_FORA0125_H.002
param_short_name=TMP2m
param_name=2-m above ground temperature
unit=k
begin_time=2007/07/01/00
end_time=2007/08/01/00
begin_time_index=249779
end_time_index=250523
lat= 28.1875
lon= -97.5625
grid_y=25
grid_x=219
tot_record=745
Request_time=Thu Apr 28 23:13:44 2016
```

Date&Time	Data
2007-07-01 00Z	3.0304E+02
2007-07-01 01Z	3.0173E+02
2007-07-01 02Z	3.0043E+02

Figure 13: Example LDAS Data Page

The scope for all of this raw data was narrowed down to a single month in two years to represent a normal to wet time period and a dry time period for comparison between the conditions. The month of July was chosen as a descriptive month for the state of Texas. The year of 2007 was a time of no drought conditions for any of the areas and so it was specified for data collection representative of a normal to wet time period. The year of 2011 was a time of some level of severe drought conditions for all of the areas examined, and was used for data collection of a dry time period.

Results and Discussion

Precipitation and Surface Runoff

Drought is the shortage of a region's water supply brought on by a period of less than average precipitation. First up was to analyze the total hourly precipitation against the drought severity grade by area in order to visually represent this relationship. The precipitation [kg/m^2] plots are presented alongside the surface runoff [kg/m^3] plots to further show what happens to the earth during a drought. Runoff happens because of precipitation. Once the precipitation reaches the surface, some of it infiltrates the soil and the rest of it is surface runoff, traveling downhill until it reaches some body of water. One factor as to the amount of precipitation that infiltrates or becomes runoff is how much moisture the ground already contains. During a drought, the ground is drier and therefore will absorb more water through infiltration, leaving less to runoff.

The plots presented in this section cover the whole time frame of 2000 to 2013. They were taken directly from the Data Rods Explorer App. The plots of precipitation and surface runoff are shown for each location in Figures 14 through 18. The drought severity grade as described above is shown in red with a right hand axis while the hydrologic variable is shown in blue with a left hand axis on each plot.

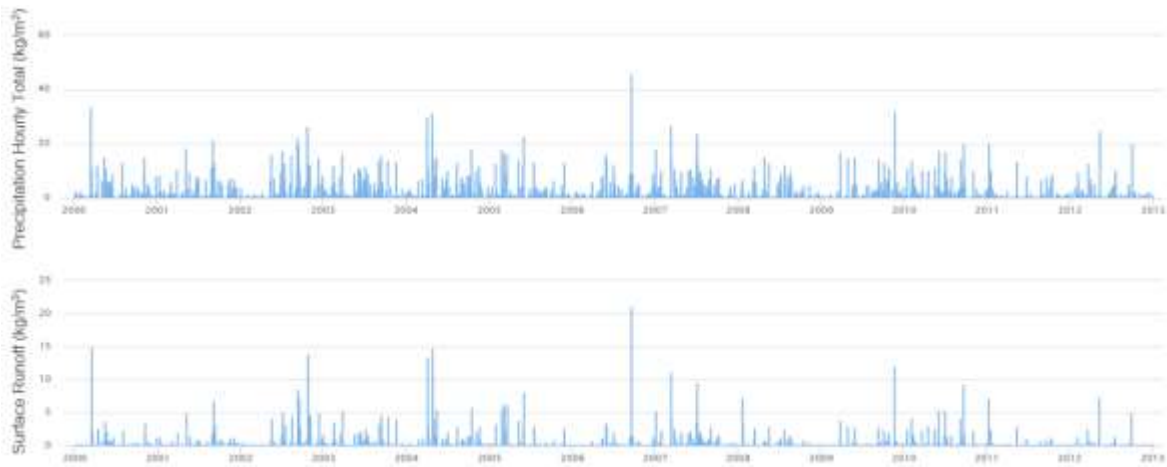


Figure 14: Corpus Christi Precipitation and Surface Runoff



Figure 15: El Paso Precipitation and Surface Runoff

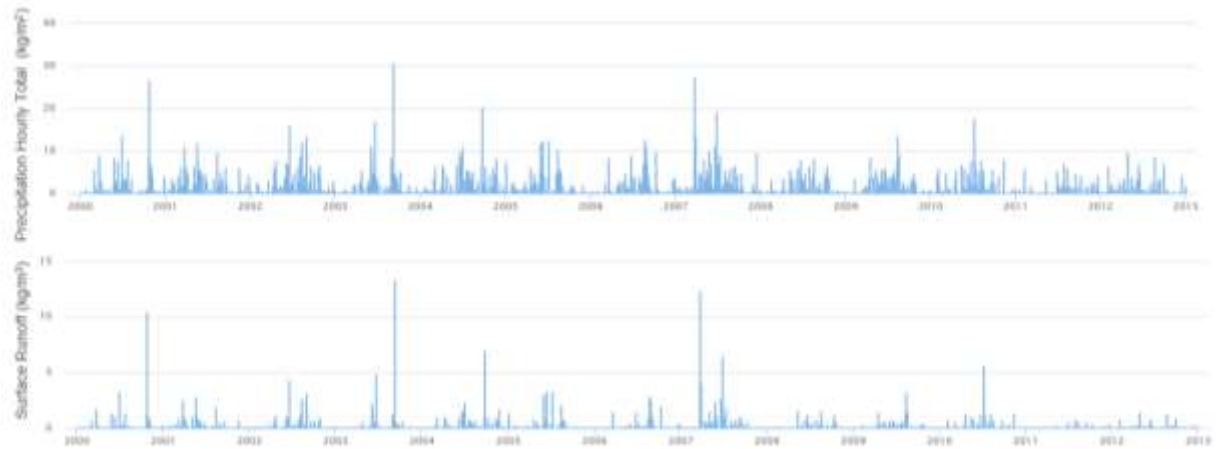


Figure 16: Amarillo Precipitation and Surface Runoff



Figure 17: Texarkana Precipitation and Surface Runoff



Figure 18: Austin Precipitation and Surface Runoff

The correlation between the precipitation and the runoff is apparent in all the sets of plots. Referring to Figure 5, there is also a correlation between the amount of precipitation that becomes surface runoff and the drought severity. While significant precipitation events still cause substantial amounts of surface runoff during severe drought, the smaller precipitation events have little to no surface runoff at these times. When the land is in severe drought, the soil and plants are all exceptionally dry and when water becomes available, they greedily soak it up. The rate of rainfall does have

an impact on how much can be soaked up by the ground, so the extreme precipitation events still show significant surface runoff because even the parched ground cannot absorb the precipitation at the rate that it is coming down. Overall, more rainfall infiltrates the soil with more severe drought while much more surface runoff is present at low to no drought. To further investigate their relationship to drought severity, the average precipitation and runoff data for the months of July 2007 and 2011 are summarized in Table 6. This includes the runoff ratio calculated for each set of averages by taking the surface runoff over the total hourly precipitation. A larger runoff ratio indicating a larger part of the precipitation becoming runoff instead of infiltrating.

Table 6: Precipitation and Runoff Summary July 2007 & 2011

		Average Total Hourly Precipitation (kg/m ²)	Average Surface Runoff (kg/m ²)	Runoff Ratio
2007	Corpus Christi	470	71.501	0.152
	El Paso	54	2.577	0.048
	Amarillo	63	5.682	0.090
	Texarkana	297	21.100	0.071
	Austin	325	30.533	0.094
2011	Corpus Christi	5	0.027	0.005
	El Paso	90	11.518	0.127
	Amarillo	33	1.406	0.042
	Texarkana	22	0.474	0.021
	Austin	5	0.022	0.005

At all of the locations except for El Paso, the runoff ration decreases during the drought conditions. This indicates that, at all the locations except El Paso, the amount of

precipitation that becomes runoff decreases during a drought, as would be expected.

The data for these time periods seem to be slightly skewed in El Paso, the area received more rain in July 2011 than it did in July 2007. This is possible because drought is a long term factor. Despite the abundant rain El Paso might have received in the one month in 2011, the overall drought severity was not significantly impacted by the event, and the region was still considered to be in some level of severe drought.

More severe drought occurs when precipitation events are less extreme and frequent, which leads to the area drying on the surface as well as underground. The next step was to look further into the effects of drought specifically in the different climate zones.

Regional Variations

The regional climatic variations of each of the five areas of interest for this report will be presented generally⁹. Then a preliminary analysis of the impact of drought on these climates will be done by looking at the temperatures [°F] in all five areas during the specified time periods representative of wet to normal conditions (2007) as well as dry conditions (2011). The following graphs depicting temperature for the five areas are all on the same scale to better represent the variations between the regions.

Corpus Christi represents the coastal region of southern Texas and has a humid subtropical climate. There is a lot of wind throughout the year. Winters are mild and summers average temperatures in the mid-90s. This area is predominantly grassland,

cropland, and ocean. Figure 19 shows the hourly temperature in Corpus Christi in July of both the wet and dry year. While the nightly lows were about the same in both years, the daily highs were significantly increased in the dry year. The maximum temperature in the wet year was 95°F and in the dry year, it jumped to 102°F.

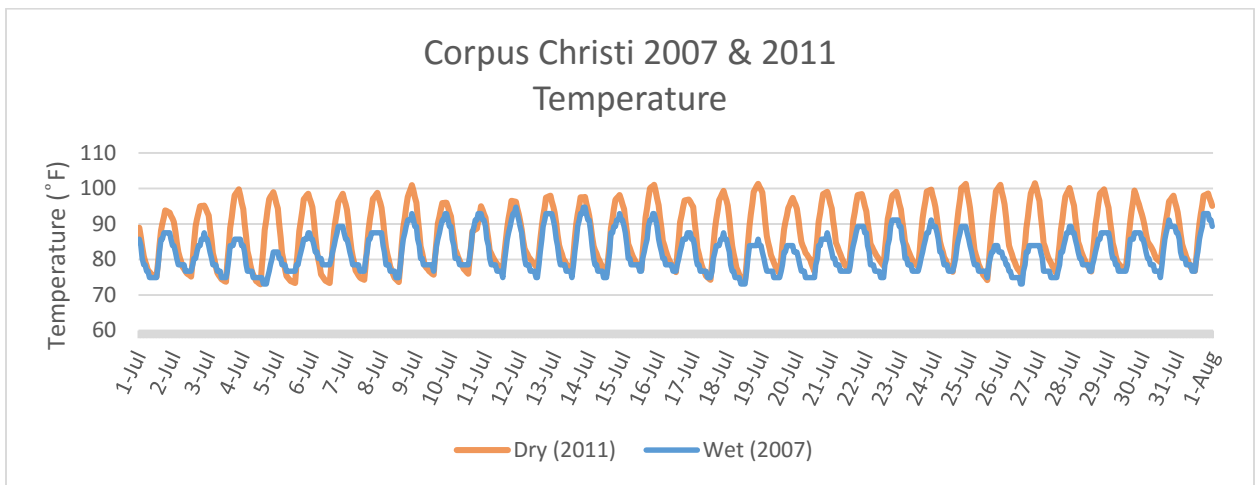


Figure 19: Corpus Christi Temperature 2007 & 2011

El Paso represents the western region of Texas and has a hot desert climate. This entails chronically low humidity, hot summers, and mild winters. A rainy season occurs July through September, during which most of the annual rainfall occurs and thunderstorms are common. In the dry season of spring, strong winds kick up sand and dust. El Paso has the highest number of average sunny days per year and the lowest average precipitation of all the identified cities. Figure 20 shows the El Paso temperature data for the month of July in both the wet and dry year. The variations from the wet year to the dry year were not nearly as severe in El Paso as in Corpus Christi. However the maximum daily temperatures were still generally a bit higher in the dry year than in the

wet. The overall maximum temperature in the wet year was less than 1 °F less than that of the dry year.

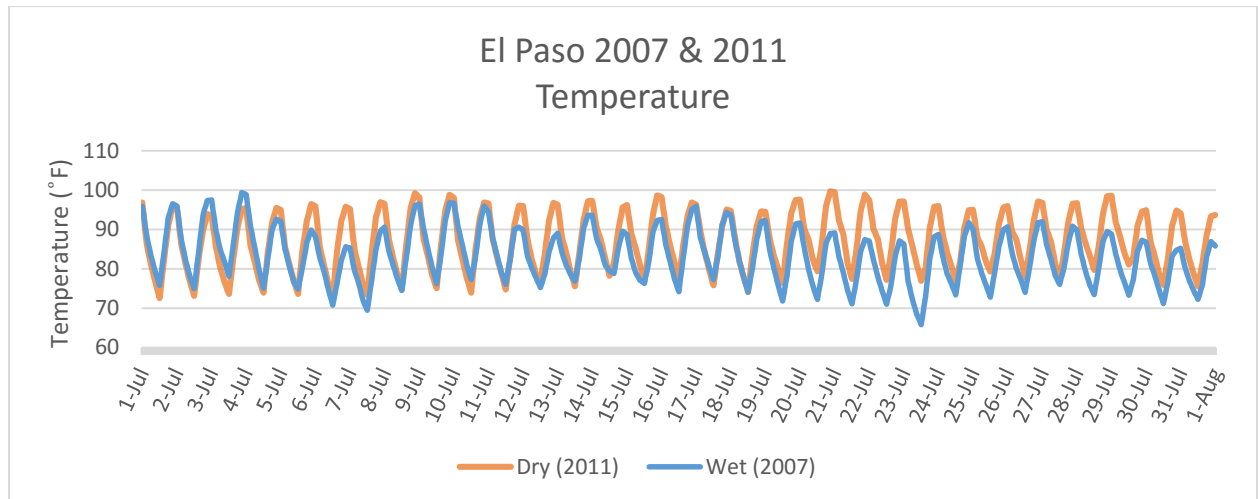


Figure 20: El Paso Temperature 2007 & 2011

Amarillo represents the northern region of Texas, with a semi-arid climate. This region is characterized by its variation of temperatures in a single day as well as day-to-day. It is the windiest region of Texas. Winter snowfall is typically light, with blizzards possible. Spring brings showers and thunderstorms more frequently than the national average, with a severity that brings the title of “Tornado Alley” to the Texas Panhandle. Figure 21 shows the temperature data of Amarillo for July of both the wet and dry year. The daily maximum temperatures of the dry year exceeded those of the wet year, similar to Corpus Christi, but more consistently. The nightly minimum temperatures of the wet year also consistently dropped lower than those of the dry year. The maximum

temperature was 97°F in the wet year and 106°F in the dry year; the minimum temperature was 65°F in the wet year and only 72°F in the dry year.

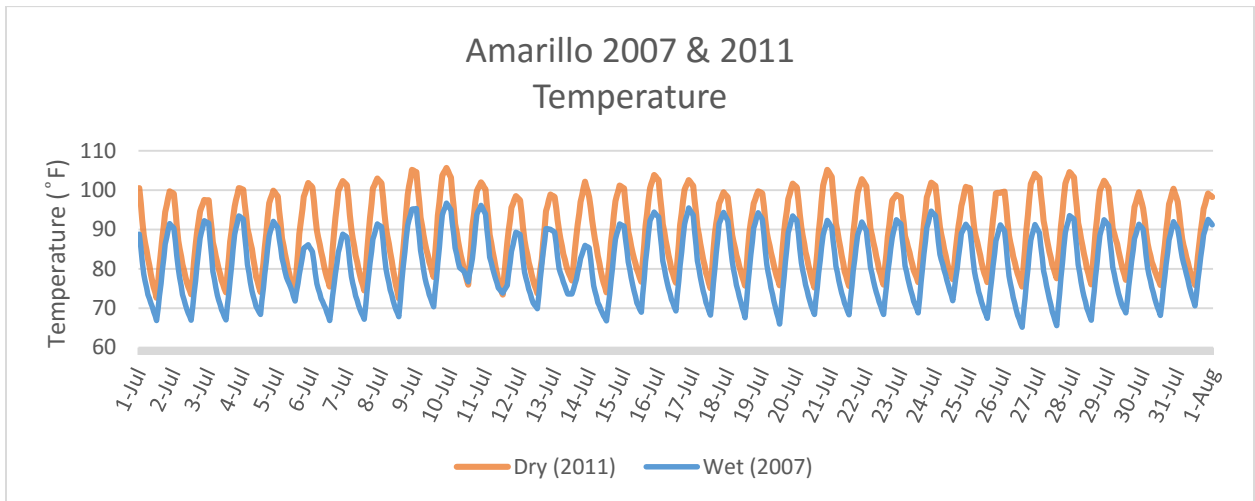


Figure 21: Amarillo Temperature 2007 & 2011

Texarkana represents the eastern region of Texas, with a warm humid temperate climate. It has the highest annual precipitation of all the identified Texas cities by almost 20 inches, and the most precipitation days. Figure 22 shows the temperature data for both the wet year and the dry year for the area. Texarkana has, by far, the most dramatic temperature changes from the wet year. The maximum temperature was 92°F in the wet year and 109°F in the dry year; the minimum temperature was 64°F in the wet year and only 75°F in the dry year.

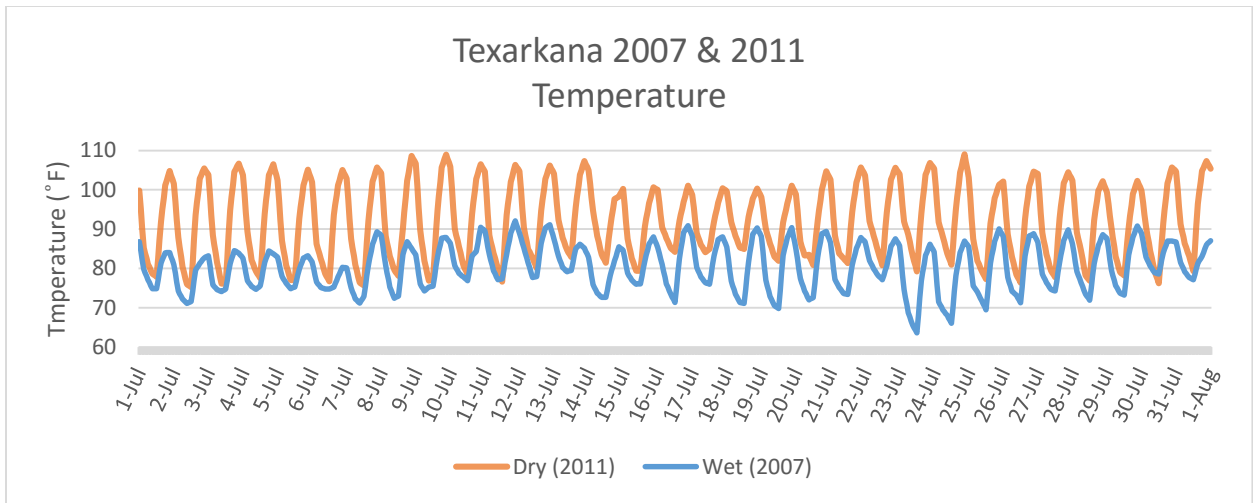


Figure 22: Texarkana Temperature 2007 & 2011

Austin represents central Texas, with a fairly humid subtropical climate. Austin is ranked second for the most rainfall as well as precipitation days of the areas of interest for this report. It is ranked right in the middle for the number of sunny days, and it has the highest average summer temperature. Figure 23 shows the temperature data for the Austin area in July of both the wet and dry years. The maximum daily temperature of the dry year exceeded that of the wet, but less dramatically and consistently than seen in Texarkana. The nightly low temperature are generally about the same from the wet year to the dry year, there seems to have been one exceptionally chilly night at the beginning of the month in the wet year.

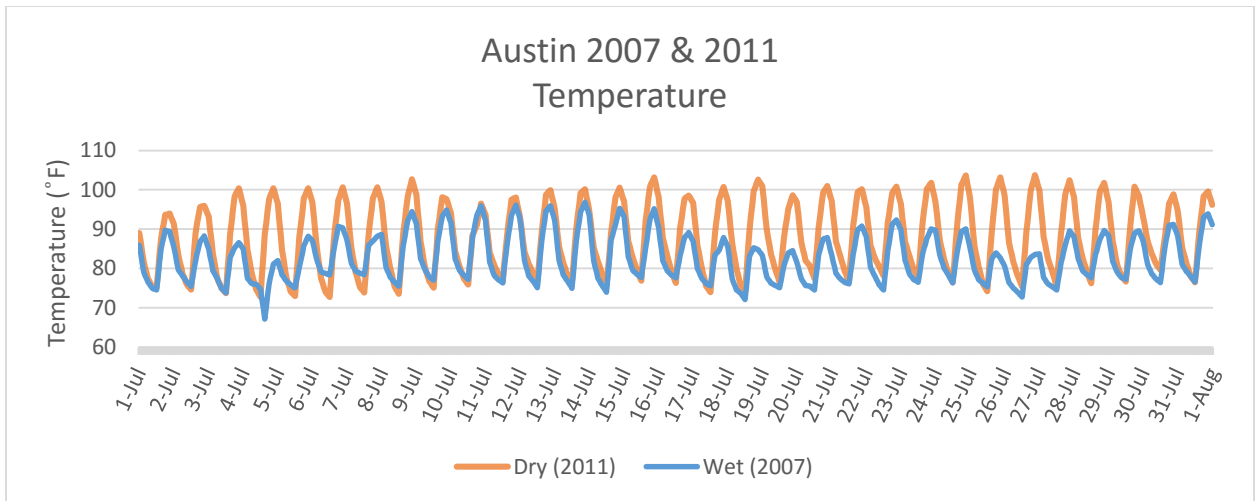


Figure 23: Austin Temperature 2007 & 2011

The temperature data presented above is summarized in Table 7. Looking at temperatures in a time of drought and a time of no drought is a preliminary analysis of the climate based reaction to drought. The impacts on the areas are similar, but not the same. Texarkana shows the biggest change from no drought to drought conditions, whereas El Paso shows the least change.

Table 7: Temperature Summary

		Average Temperature (°F)	Maximum Temperature (°F)
2007	Corpus Christi	82	95
	El Paso	83	99
	Amarillo	81	97
	Texarkana	80	92
	Austin	83	97
2011	Corpus Christi	87	101
	El Paso	87	100
	Amarillo	89	106
	Texarkana	92	109
	Austin	88	104

Evapotranspiration

To further investigate the climatic reaction to drought, the humidity must be accounted for. Evapotranspiration serves as a preliminary view of the humidity of an area.

Evapotranspiration is considered to be the water lost to the atmosphere from the ground and from plant leaves, and from surface waters. When the humidity is higher, the air cannot absorb as much water evaporation from the ground and plants, and vice versa. Therefore, a higher evapotranspiration indicates a lower level of humidity. The evapotranspiration [mm/s] data are presented similarly to the temperature data above, for the months of July in 2007 and 2011 to show a period of normal/wet conditions as well as dry conditions. These plots are shown for each location in Figures 24 through 28. Note that the axis is not on the same for all of the graphs.

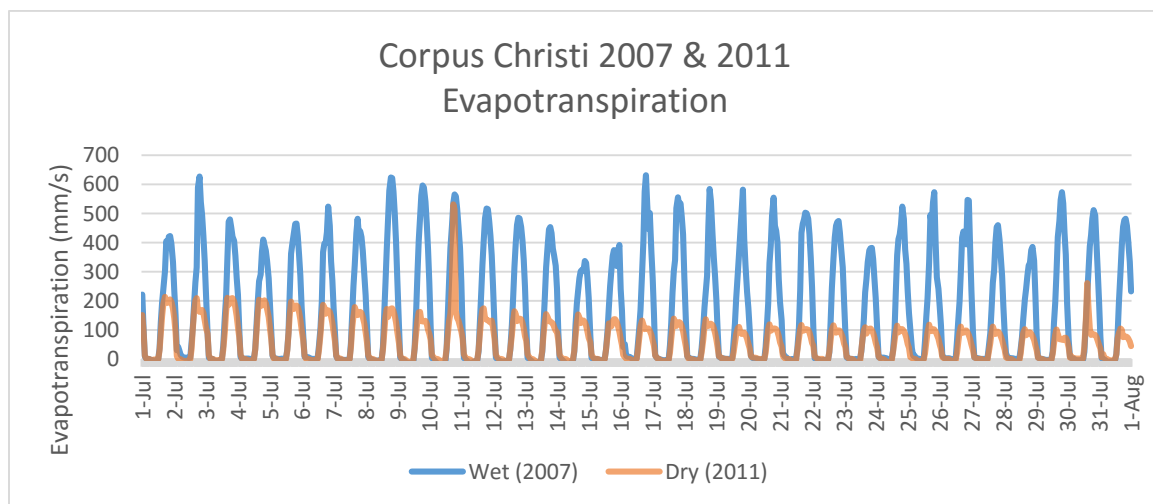


Figure 24: Corpus Christi Evapotranspiration 2007 & 2011

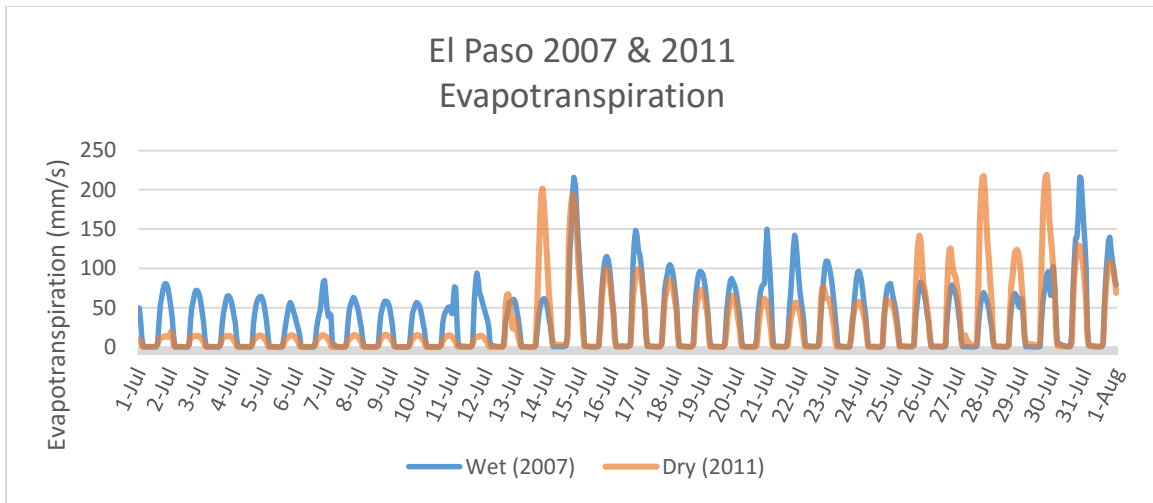


Figure 25: El Paso Evapotranspiration 2007 & 2011

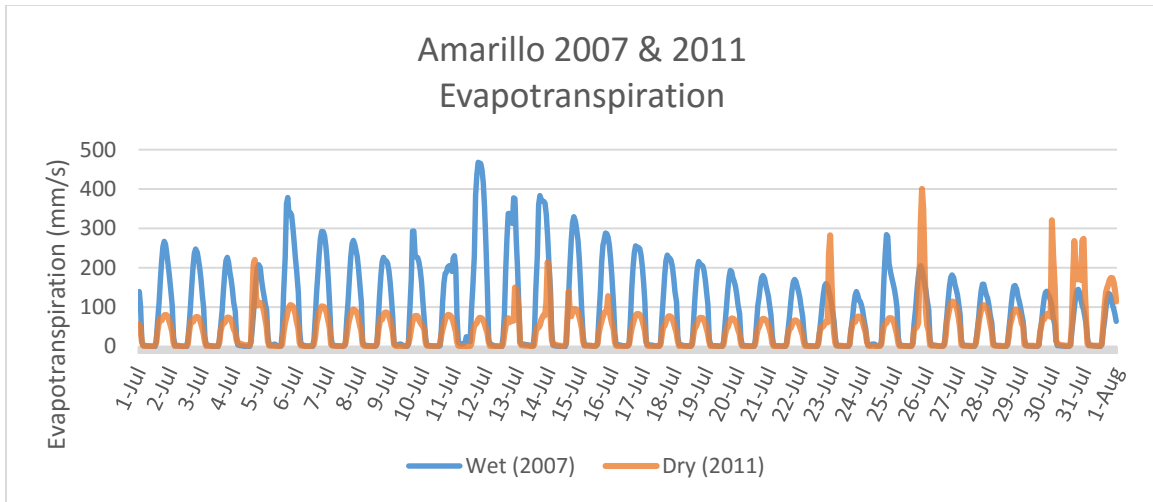


Figure 26: Amarillo Evapotranspiration 2007 & 2011

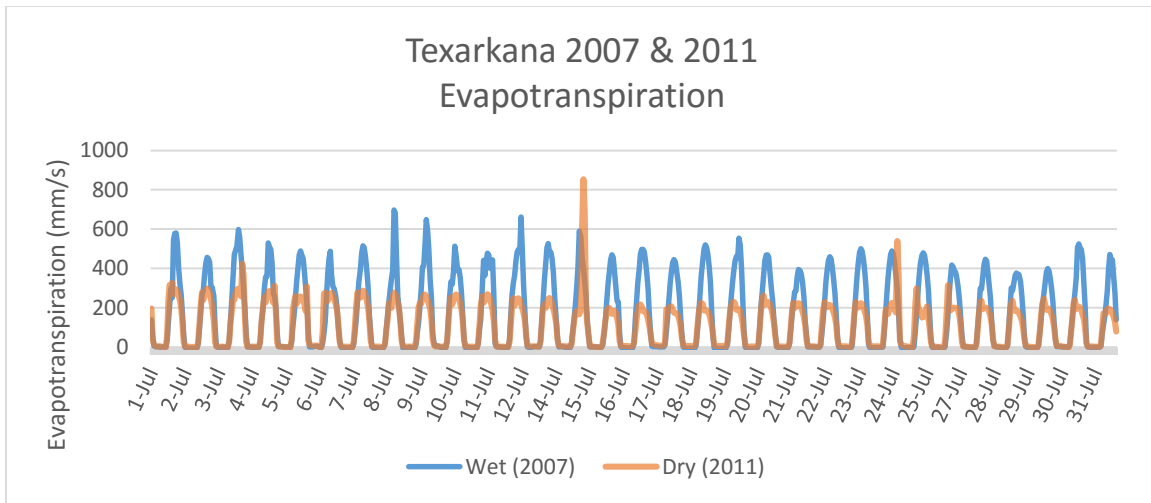


Figure 27: Texarkana Evapotranspiration 2007 & 2011

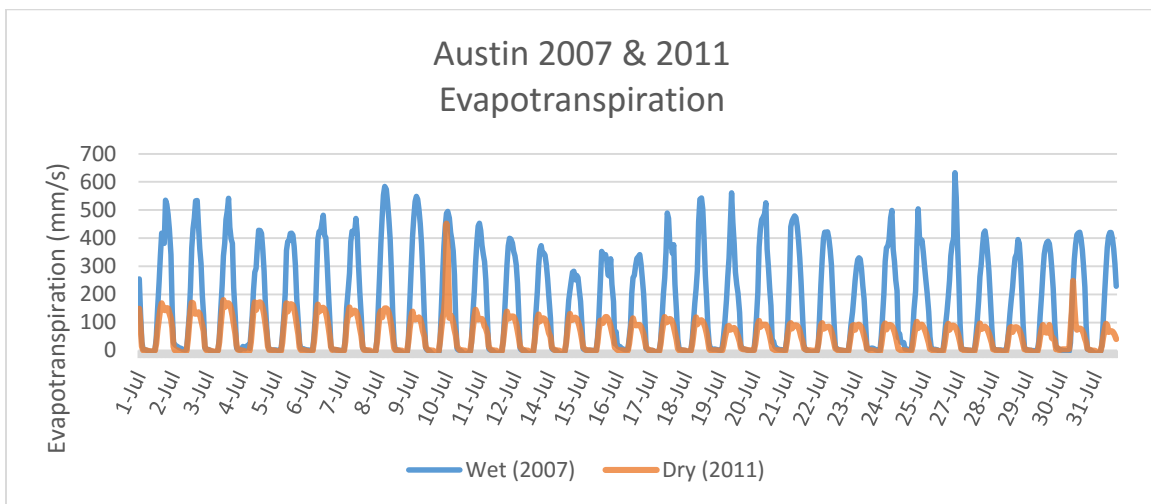


Figure 28: Austin Evapotranspiration 2007 & 2011

A summary of the evapotranspiration data for all regions is shown in Table 8. In all of the regions, there is generally a large increase in evapotranspiration under normal to wet conditions. This is because the amount of water that plants transpire is dependent upon the soil moisture availability as well as the air temperature and humidity. Higher air temperatures cause the plant cells that control the openings which release water to

the atmosphere to open, causing more water loss. However, as drought severity increases, the available soil moisture is declines and plants begin to senesce (shed leaves) allowing less water loss ³.

Table 8: Evapotranspiration Summary

		Average Evapotranspiration (mm/s)	Maximum Evapotranspiration (mm/s)
2007	Corpus Christi	166	531
	El Paso	33	219
	Amarillo	88	400
	Texarkana	166	854
	Austin	158	452
2011	Corpus Christi	57	531
	El Paso	27	219
	Amarillo	41	400
	Texarkana	107	854
	Austin	50	452

This dependence on available soil moisture for evapotranspiration outweighs the change in humidity due to drought conditions. So evapotranspiration may give insight into the humidity of an area under normal or wet conditions, it does not give a full picture under drought conditions. A different analysis must be done to look at humidity of an area in reference to drought; the Bowen ratio is another indicator of humidity, unbiased by soil moisture.

Bowen Ratio

The Bowen ratio is the ratio of sensible heat flux [W/m^2] to latent heat flux [W/m^2].

Sensible heat flux is the heat transfer from Earth's surface to the atmosphere by conduction and convection. Conduction is the transfer of heat from high temperature to low temperature due to direct contact, whereas convection is the transport of heat through indirect contact, air movements. Latent heat flux is the heat transfer related to phase change. Considerable energy is absorbed in the process of changing water from a liquid to a vapor, this energy is consumed as heat from the surface for evaporation ¹.

A Bowen ratio of greater than one indicates that the area is arid because the sensible heat flux is greater than the latent heat flux; most of the energy released from the surface happens by heating the air. A Bowen ratio of less than one indicates that the area is humid because the latent heat flux is greater than the sensible heat flux; the majority of the energy being released from the surface is due to evaporating water.

Table 9 shows the average sensible and latent heat fluxes for all five areas over the entire year of 2007 as well month of July in 2007 and 2011. From these averages, the Bowen ratio for the area was calculated. The Bowen ratios for the entire year of 2007 represent a realistic number typical for each area and those for the months of July 2007 & 2011 illustrate the effects of normal to wet conditions and dry conditions.

Table 9: Heat Flux and Bowen Ratio Summary

		Average Sensible Heat Flux (W/m ²)	Average Latent Heat Flux (W/m ²)	Bowen Ratio
Year 2007	Corpus	45	66	0.67
	El Paso	63	17	3.72
	Amarillo	50	40	1.25
	Texarkana	46	63	0.74
	Austin	48	62	0.78
July 2007	Corpus Christi	40	115	0.35
	El Paso	96	23	4.12
	Amarillo	100	61	1.64
	Texarkana	47	116	0.41
	Austin	44	109	0.41
July 2011	Corpus Christi	152	40	3.83
	El Paso	105	19	5.63
	Amarillo	120	29	4.20
	Texarkana	114	74	1.54
	Austin	153	35	4.41

The year averages indicate that El Paso and Amarillo are the only arid regions, with El Paso ranking significantly drier. While Corpus Christi, Texarkana, and Austin would all be considered humid. These Bowen ratios support the general claims made previously about the climates of all of the areas.

In the 2007 part of this table, the humid areas reflect what would be expected of a wetter period, a smaller Bowen ratio indicating an increase in humidity. The arid regions however, both increased in Bowen ratio reflecting a drier period. This could be attributed to the time period examined was a summer month which would likely be drier than the yearly average.

The 2011 portion of this table shows large jumps in the Bowen ratio for all five areas. During some level of severe drought conditions, all climates show a drop in air humidity. The humid areas decrease enough to register as arid. These values show that during a drought, it is like the humid areas are picked up and moved into the desert. Austin showed the most dramatic change with an increase in the Bowen ratio of 4.

Having fully explored climate through temperature and humidity of all five areas, and how these change under drought conditions, the next step was to investigate the incoming energy to these areas.

Incoming Energy

The incoming energy to the Earth's surface at a specific location can be measured in the net radiation [W/m^2]. Solar radiation is shortwave radiation, and radiation originating from the earth is longwave radiation. Net shortwave radiation flux is the amount of incident solar shortwave radiation absorbed by the earth per unit area. This is found by the difference between incoming solar shortwave radiation and shortwave radiation reflected by the earth's surface. Shortwave radiation fluctuates greatly with the time of the day since there is no sun to radiate at night. Net longwave radiation flux is the amount of longwave radiation absorbed by the earth per unit area. This is found by the difference between the incident longwave counter-radiation and outgoing longwave radiation. Longwave radiation is not nearly as inconsistent as shortwave radiation, but still has a diurnal pattern. The net shortwave radiation flux and net longwave radiation

flux data are presented for all five locations for the month of July in 2007 and 2011 in Figures 29 through 33 to show the change of incoming energy from both sources of radiation during a wet time period and a dry time period.

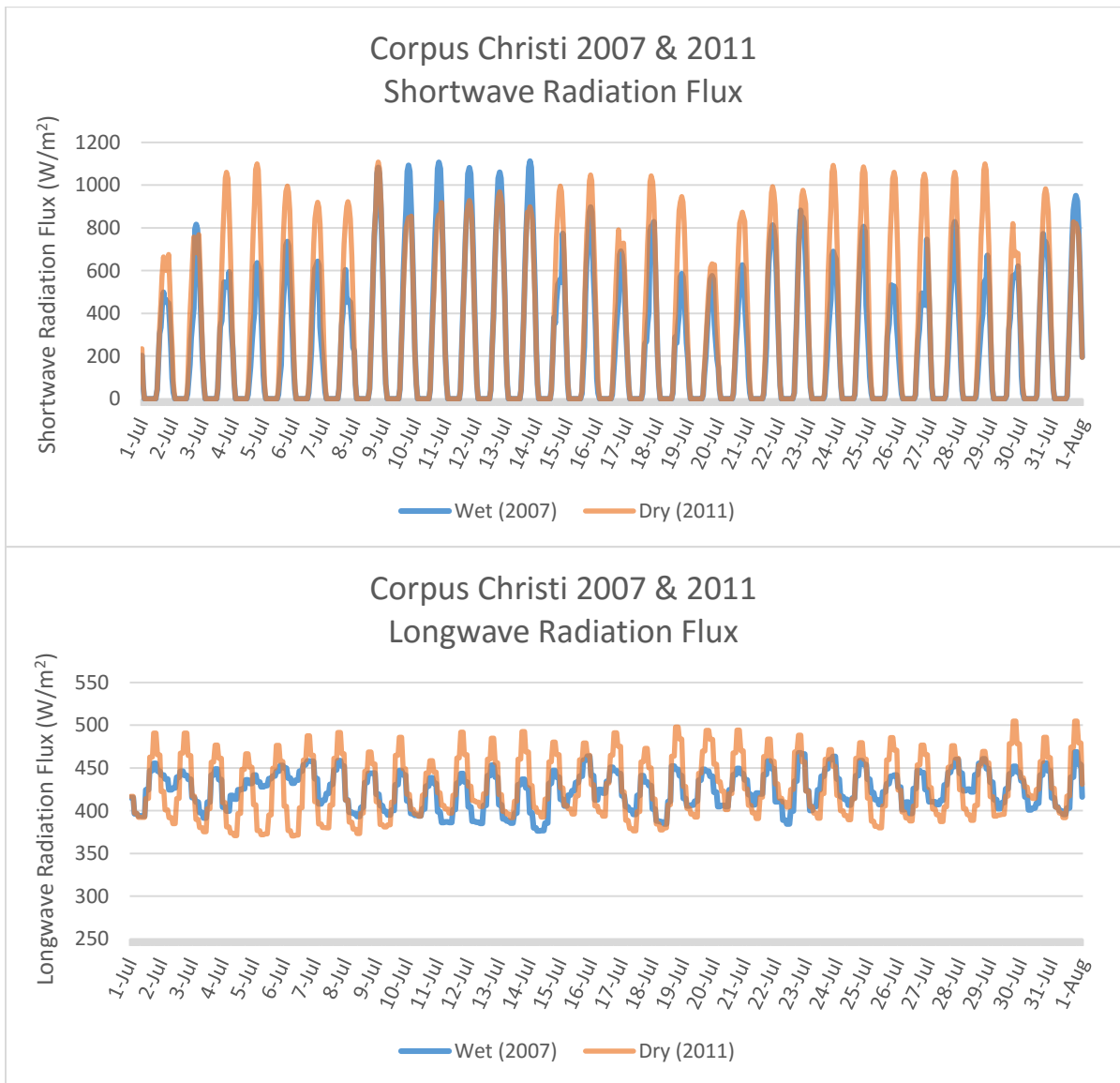


Figure 29: Corpus Christi 2007 & 2011 Net Shortwave & Longwave Radiation Flux

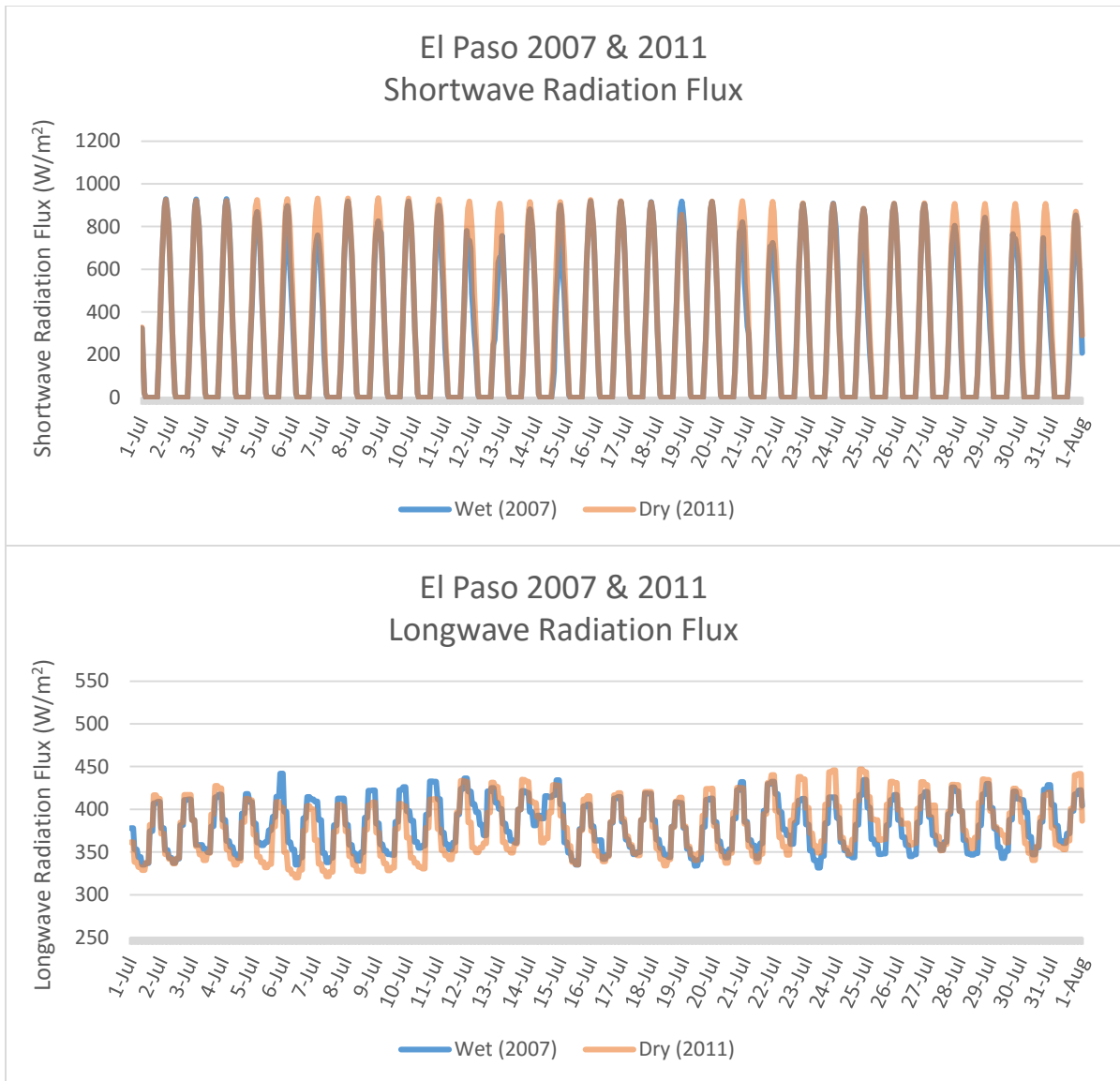


Figure 30: El Paso 2007 & 2011 Net Shortwave & Longwave Radiation Flux

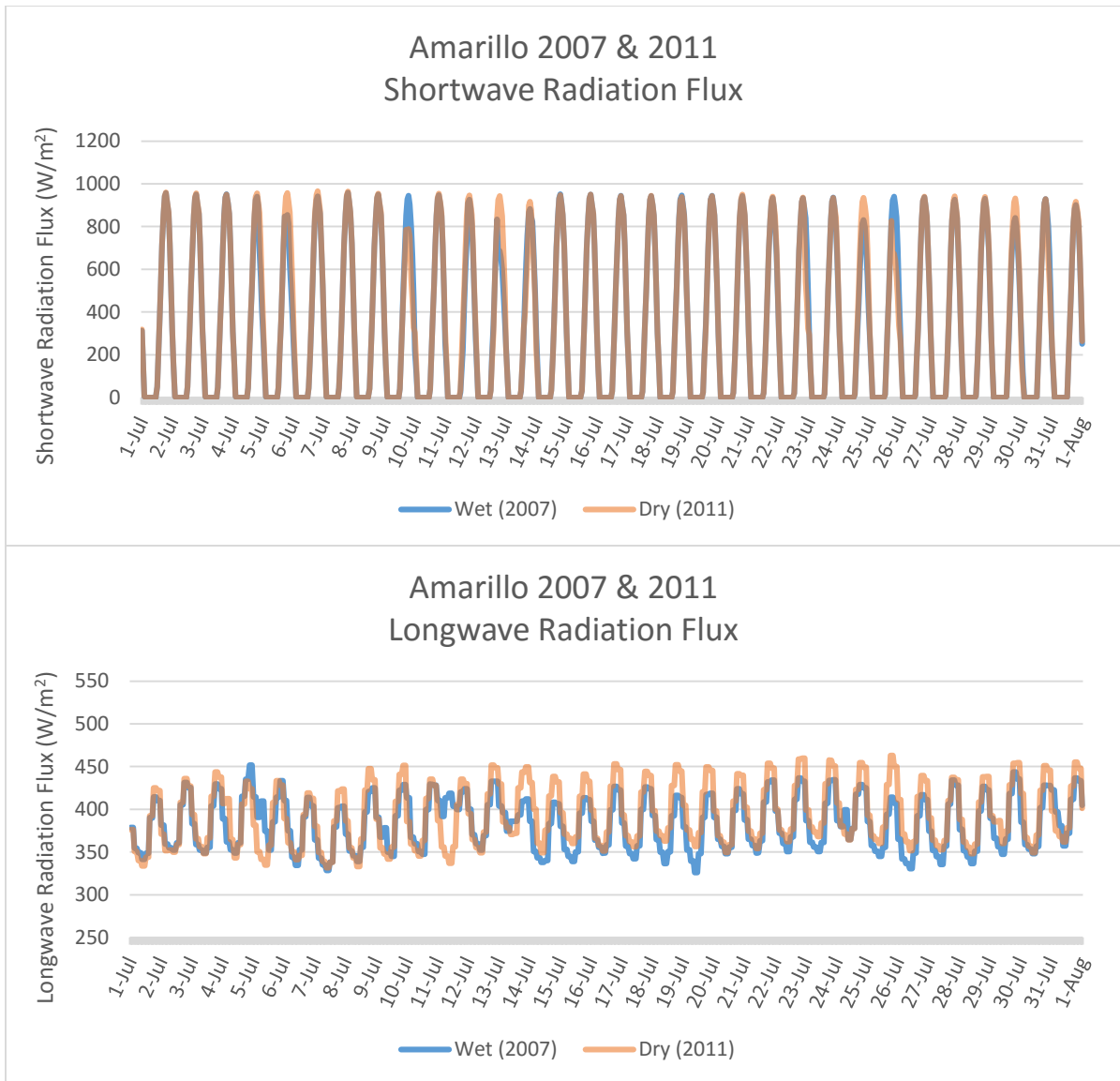


Figure 31: Amarillo 2007 & 2011 Net Shortwave & Longwave Radiation Flux

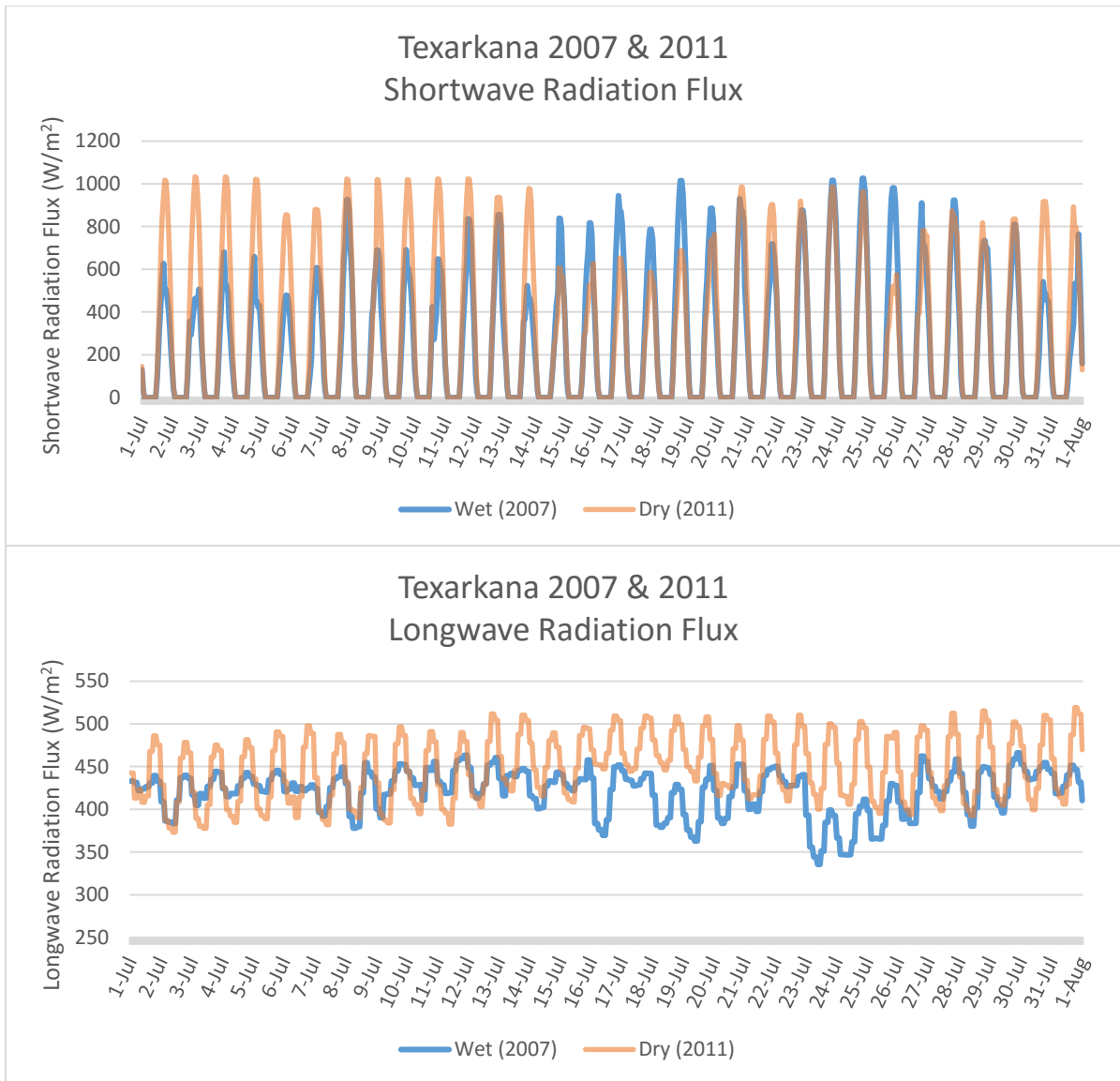


Figure 32: Texarkana 2007 & 2011 Net Shortwave & Longwave Radiation Flux

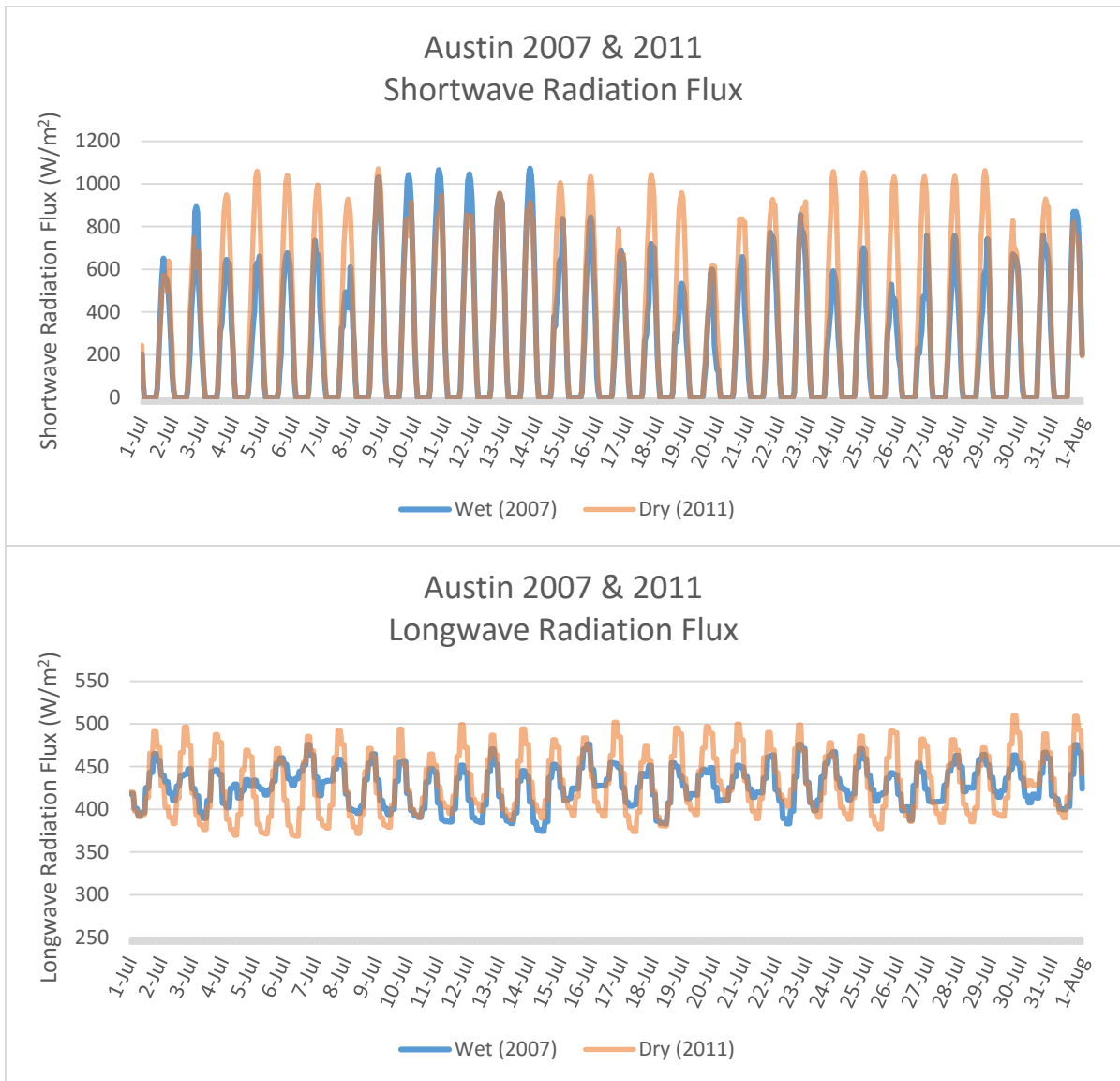


Figure 33: Austin 2007 & 2011 Net Shortwave & Longwave Radiation Flux

Amarillo and El Paso show very consistent peak daily net shortwave radiation flux values. They also had the least change in net shortwave radiation flux from the wet time period to the dry time period. Amarillo has the highest average net shortwave radiation flux, but Austin had the highest maximum. The wet period net longwave radiation flux

vary a lot day to day, but were all generally within the same bounds overall. Austin had the highest average net longwave radiation flux, as well as the highest maximum. The net shortwave and longwave radiation flux data are summarized for both time periods in Table 10. At each of these locations, the surface receives more energy from the longwave radiation that is reflected from the atmosphere than it does from shortwave radiation from the sun. This highlights the importance of global warming, since an increase in greenhouse gasses means more particles in the atmosphere which increases the amount of longwave radiation that is reflected back to the earth.

Table 10: 2007 & 2011 Net Radiation Flux Summary

		Average Net Shortwave Radiation Flux (W/m ²)	Maximum Net Shortwave Radiation Flux (W/m ²)	Average Net Longwave Radiation Flux (W/m ²)	Maximum Net Longwave Radiation Flux (W/m ²)
2007	Corpus Christi	250	1112	424	469
	El Paso	284	929	381	442
	Amarillo	319	959	383	452
	Texarkana	254	1026	421	466
	Austin	249	1072	427	476
2011	Corpus Christi	322	1108	428	505
	El Paso	305	934	378	447
	Amarillo	322	966	393	463
	Texarkana	299	1033	448	519
	Austin	318	1071	430	510

The daily peak net shortwave and longwave radiation flux was mostly greater during the drought than during the wet period at all locations, several days were a bit lower and the relative difference depended on the location. The average net shortwave radiation

flux were higher during the drought at every location, and the same is true for net longwave radiation flux except in El Paso which dipped in the average value. By far, the most remarkable trend among these was the dramatic increase in the net longwave radiation flux in Texarkana from the wet period to the dry.

Conclusion

This report visually represented the cause and effects of drought in five very different climatic regions of Texas. The plots pulled from the Data Rods Explorer App served as a fast and easy way to correlate drought data with precipitation data. An additional such plot alongside those showed the effects of drought on the land, specifically during a precipitation event. When there has been a lack of precipitation, the earth become greedy for that water and leaves less water for surface runoff than would otherwise be the case.

The variations between the areas investigated were presented and first analyzed through the impacts on temperature. Every single area showed an increase in daily temperatures from the wet time period to the dry. Texarkana had the most significant increase in daily temperatures, but the least significant drought severity grade for the time period of analysis. This shows what is already known, that Texarkana is the wettest of the five areas. Therefore, any drought will have significant impacts on that area. The opposite is true for El Paso. El Paso had the smallest change in daily temperatures. It is the driest region and drought effects it the least of the locations.

To support the claims of how wet or dry the regions are, the evapotranspiration was first examined. This proved to be an ineffective method of analysis for humidity of an area because evapotranspiration is heavily reliant on the available soil moisture, which

declines with drought severity, forcing a decline in evapotranspiration despite more opportunity for air to absorb moisture. Then, the relative heat flux distribution of the regions was accessed as an indicator of humidity unbiased by the soil moisture content by the Bowen ratio. The climatic claims held true under the Bowen ratio analysis. El Paso was shown as the most arid region and saw the least change in its Bowen ratio due to drought. All of the humid areas saw a greater impact of drought, changing their Bowen ratios to reflect an arid climate for that time period.

To take the investigation of drought in the five regions further, the incoming energy was examined by net radiation to the surface. Here again, the arid regions of El Paso and Amarillo saw the least amount of change in overall net radiation to the surface during drought, but all of the areas saw some increase in incoming energy via radiation.

In conclusion, humid areas are more dramatically impacted by droughts than arid conditions, but only in the sense that humid regions under drought conditions become more similar to arid regions under normal conditions. Regions typically arid see less change under drought conditions, other than the obvious potential water shortage.

Appendix

**For Katie Born
From D.Arctur**

4/20/2016

NLDAS variables info: <http://disc.sci.gsfc.nasa.gov/hydrology/data-rods-time-series-data>

Variable

1	2-m above ground temperature	forcing
2	Surface DW shortwave radiation flux	forcing
3	Surface DW longwave radiation flux	forcing
4	evapotranspiration	noah
5	latent heat flux	noah
6	sensible heat flux	noah
7	precipitation hourly total	forcing
8	surface runoff	noah

Corpus Christi

Wet July 2007

Dry July 2011

1	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_FORA0125_H.002:TMP2m&startDate=2007-07-01T00&endDate=2007-08-01T00&location=GEOM:POINT%28-97.5785,%2028.1507%29&type=asc2	-	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_FORA0125_H.002:TMP2m&startDate=2011-07-01T00&endDate=2011-08-01T00&location=GEOM:POINT%28-97.5785,%2028.1507%29&type=asc2
2	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_FORA0125_H.002:DSWRFsfc&startDate=2007-07-01T00&endDate=2007-08-01T00&location=GEOM:POINT%28-97.5785,%2028.1507%29&type=asc2	-	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_FORA0125_H.002:DSWRFsfc&startDate=2011-07-01T00&endDate=2011-08-01T00&location=GEOM:POINT%28-97.5785,%2028.1507%29&type=asc2
3	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_FORA0125_H.002:DLWRFsfc&startDate=2007-07-01T00&endDate=2007-08-01T00&location=GEOM:POINT%28-97.5785,%2028.1507%29&type=asc2	-	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_FORA0125_H.002:DLWRFsfc&startDate=2011-07-01T00&endDate=2011-08-01T00&location=GEOM:POINT%28-97.5785,%2028.1507%29&type=asc2

4	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_NOAH0125_H.002:EVPSfc&startDate=2007-07-01T00&endDate=2007-08-01T00&location=GEOM:POINT%28-97.5785,%2028.1507%29&type=asc2	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_NOAH0125_H.002:EVPSfc&startDate=2011-07-01T00&endDate=2011-08-01T00&location=GEOM:POINT%28-97.5785,%2028.1507%29&type=asc2
5	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_NOAH0125_H.002:LHTFLsfc&startDate=2007-07-01T00&endDate=2007-08-01T00&location=GEOM:POINT%28-97.5785,%2028.1507%29&type=asc2	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_NOAH0125_H.002:LHTFLsfc&startDate=2011-07-01T00&endDate=2011-08-01T00&location=GEOM:POINT%28-97.5785,%2028.1507%29&type=asc2
6	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_NOAH0125_H.002:SHTFLsfc&startDate=2007-07-01T00&endDate=2007-08-01T00&location=GEOM:POINT%28-97.5785,%2028.1507%29&type=asc2	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_NOAH0125_H.002:SHTFLsfc&startDate=2011-07-01T00&endDate=2011-08-01T00&location=GEOM:POINT%28-97.5785,%2028.1507%29&type=asc2
7	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_FORA0125_H.002:APCPsfc&startDate=2007-07-01T00&endDate=2007-08-01T00&location=GEOM:POINT%28-97.5785,%2028.1507%29&type=asc2	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_FORA0125_H.002:APCPsfc&startDate=2011-07-01T00&endDate=2011-08-01T00&location=GEOM:POINT%28-97.5785,%2028.1507%29&type=asc2
8	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_NOAH0125_H.002:SSRUNsfc&startDate=2007-07-01T00&endDate=2007-08-01T00&location=GEOM:POINT%28-105.951,%2031.6089%29&type=asc2	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_NOAH0125_H.002:SSRUNsfc&startDate=2011-07-01T00&endDate=2011-08-01T00&location=GEOM:POINT%28-105.951,%2031.6089%29&type=asc2

El Paso

1	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_FORA0125_H.002:TMP2m&startDate=2007-07-01T00&endDate=2007-08-01T00&location=GEOM:POINT%28-105.951,%2031.6089%29&type=asc2	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_FORA0125_H.002:TMP2m&startDate=2011-07-01T00&endDate=2011-08-01T00&location=GEOM:POINT%28-105.951,%2031.6089%29&type=asc2
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2	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_FORA0125_H.002:DSWRFsfc&startDate=2007-07-01T00&endDate=2007-08-01T00&location=GEOM:POINT%28-105.951,%2031.6089%29&type=asc2	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_FORA0125_H.002:DSWRFsfc&startDate=2011-07-01T00&endDate=2011-08-01T00&location=GEOM:POINT%28-105.951,%2031.6089%29&type=asc2
3	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_FORA0125_H.002:DLWRFsfc&startDate=2007-07-01T00&endDate=2007-08-01T00&location=GEOM:POINT%28-105.951,%2031.6089%29&type=asc2	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_FORA0125_H.002:DLWRFsfc&startDate=2011-07-01T00&endDate=2011-08-01T00&location=GEOM:POINT%28-105.951,%2031.6089%29&type=asc2
4	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_NOAH0125_H.002:EVPSfc&startDate=2007-07-01T00&endDate=2007-08-01T00&location=GEOM:POINT%28-105.951,%2031.6089%29&type=asc2	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_NOAH0125_H.002:EVPSfc&startDate=2011-07-01T00&endDate=2011-08-01T00&location=GEOM:POINT%28-105.951,%2031.6089%29&type=asc2
5	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_NOAH0125_H.002:LHTFLsfc&startDate=2007-07-01T00&endDate=2007-08-01T00&location=GEOM:POINT%28-105.951,%2031.6089%29&type=asc2	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_NOAH0125_H.002:LHTFLsfc&startDate=2011-07-01T00&endDate=2011-08-01T00&location=GEOM:POINT%28-105.951,%2031.6089%29&type=asc2
6	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_NOAH0125_H.002:SHTFLsfc&startDate=2007-07-01T00&endDate=2007-08-01T00&location=GEOM:POINT%28-105.951,%2031.6089%29&type=asc2	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_NOAH0125_H.002:SHTFLsfc&startDate=2011-07-01T00&endDate=2011-08-01T00&location=GEOM:POINT%28-105.951,%2031.6089%29&type=asc2
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Amarillo

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Texarkana

1	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_FORA0125_H.002:TMP2m&startDate=2007-07-01T00&endDate=2007-08-01T00&location=GEOM:POINT%28-94.5099,%2033.3397%29&type=asc2	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_FORA0125_H.002:TMP2m&startDate=2011-07-01T00&endDate=2011-08-01T00&location=GEOM:POINT%28-94.5099,%2033.3397%29&type=asc2
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3	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_FORA0125_H.002:DLWRFsfc&startDate=2007-07-01T00&endDate=2007-08-01T00&location=GEOM:POINT%28-94.5099,%2033.3397%29&type=asc2	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_FORA0125_H.002:DLWRFsfc&startDate=2011-07-01T00&endDate=2011-08-01T00&location=GEOM:POINT%28-94.5099,%2033.3397%29&type=asc2

4	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_NOAH0125_H.002:EVPSfc&startDate=2007-07-01T00&endDate=2007-08-01T00&location=GEOM:POINT%28-94.5099,%2033.3397%29&type=asc2	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_NOAH0125_H.002:EVPSfc&startDate=2011-07-01T00&endDate=2011-08-01T00&location=GEOM:POINT%28-94.5099,%2033.3397%29&type=asc2
5	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_NOAH0125_H.002:LHTFLsfc&startDate=2007-07-01T00&endDate=2007-08-01T00&location=GEOM:POINT%28-94.5099,%2033.3397%29&type=asc2	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_NOAH0125_H.002:LHTFLsfc&startDate=2011-07-01T00&endDate=2011-08-01T00&location=GEOM:POINT%28-94.5099,%2033.3397%29&type=asc2
6	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_NOAH0125_H.002:SHTFLsfc&startDate=2007-07-01T00&endDate=2007-08-01T00&location=GEOM:POINT%28-94.5099,%2033.3397%29&type=asc2	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_NOAH0125_H.002:SHTFLsfc&startDate=2011-07-01T00&endDate=2011-08-01T00&location=GEOM:POINT%28-94.5099,%2033.3397%29&type=asc2
7	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_FORA0125_H.002:APCPsfc&startDate=2007-07-01T00&endDate=2007-08-01T00&location=GEOM:POINT%28-94.5099,%2033.3397%29&type=asc2	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_FORA0125_H.002:APCPsfc&startDate=2011-07-01T00&endDate=2011-08-01T00&location=GEOM:POINT%28-94.5099,%2033.3397%29&type=asc2
8	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_NOAH0125_H.002:SSRUNsfc&startDate=2007-07-01T00&endDate=2007-08-01T00&location=GEOM:POINT%28-94.5099,%2033.3397%29&type=asc2	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_NOAH0125_H.002:SSRUNsfc&startDate=2011-07-01T00&endDate=2011-08-01T00&location=GEOM:POINT%28-94.5099,%2033.3397%29&type=asc2

Austin

1	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_FORA0125_H.002:TMP2m&startDate=2007-07-01T00&endDate=2007-08-01T00&location=GEOM:POINT%28-97.9136,%2028.1507%29&type=asc2	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_FORA0125_H.002:TMP2m&startDate=2011-07-01T00&endDate=2011-08-01T00&location=GEOM:POINT%28-97.9136,%2028.1507%29&type=asc2
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2	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_FORA0125_H.002:DSWRFsfc&startDate=2007-07-01T00&endDate=2007-08-01T00&location=GEOM:POINT%28-97.9136,%2028.1507%29&type=asc2	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_FORA0125_H.002:DSWRFsfc&startDate=2011-07-01T00&endDate=2011-08-01T00&location=GEOM:POINT%28-97.9136,%2028.1507%29&type=asc2
3	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_FORA0125_H.002:DLWRFsfc&startDate=2007-07-01T00&endDate=2007-08-01T00&location=GEOM:POINT%28-97.9136,%2028.1507%29&type=asc2	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_FORA0125_H.002:DLWRFsfc&startDate=2011-07-01T00&endDate=2011-08-01T00&location=GEOM:POINT%28-97.9136,%2028.1507%29&type=asc2
4	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_NOAH0125_H.002:EVPSfc&startDate=2007-07-01T00&endDate=2007-08-01T00&location=GEOM:POINT%28-97.9136,%2028.1507%29&type=asc2	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_NOAH0125_H.002:EVPSfc&startDate=2011-07-01T00&endDate=2011-08-01T00&location=GEOM:POINT%28-97.9136,%2028.1507%29&type=asc2
5	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_NOAH0125_H.002:LHTFLsfc&startDate=2007-07-01T00&endDate=2007-08-01T00&location=GEOM:POINT%28-97.9136,%2028.1507%29&type=asc2	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_NOAH0125_H.002:LHTFLsfc&startDate=2011-07-01T00&endDate=2011-08-01T00&location=GEOM:POINT%28-97.9136,%2028.1507%29&type=asc2
6	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_NOAH0125_H.002:SHTFLsfc&startDate=2007-07-01T00&endDate=2007-08-01T00&location=GEOM:POINT%28-97.9136,%2028.1507%29&type=asc2	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_NOAH0125_H.002:SHTFLsfc&startDate=2011-07-01T00&endDate=2011-08-01T00&location=GEOM:POINT%28-97.9136,%2028.1507%29&type=asc2
7	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_FORA0125_H.002:APCPsfc&startDate=2007-07-01T00&endDate=2007-08-01T00&location=GEOM:POINT%28-97.9136,%2028.1507%29&type=asc2	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_FORA0125_H.002:APCPsfc&startDate=2011-07-01T00&endDate=2011-08-01T00&location=GEOM:POINT%28-97.9136,%2028.1507%29&type=asc2

8	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_NOAH0125_H.002:SSRUNsfc&startDate=2007-07-01T00&endDate=2007-08-01T00&location=GEOM:POINT%28-97.91369,%2028.1507%29&type=asc2	http://hydro1.sci.gsfc.nasa.gov/daac-bin/access/timeseries.cgi?variable=NLDAS:NLDAS_NOAH0125_H.002:SSRUNsfc&startDate=2011-07-01T00&endDate=2011-08-01T00&location=GEOM:POINT%28-97.91369,%2028.1507%29&type=asc2
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